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Frank Schlesinger
1871-1943

By IDA BARNEY

Dr. Frank Schlesinger, Professor Emeritus of Astronomy and Director Emeritus of the Astronomical Observatory in Yale University, died on July 10, 1943, at his home in Lyme, Connecticut. His death brought a feeling of deep loss to astronomers all over the world. Many of them were his friends and valued him highly both as a scientist and as a man. Others knew him only as a leader in astronomical research who had done work of the greatest importance in such fundamental fields as the determination of stellar distances and the derivation of star positions of the highest accuracy. He was a pioneer in many fields, solving old problems in new ways. He used the photographic plate as it had not been used before in astronomy, and made it yield results of the greatest precision by considering in his reductions all sources of error.

Dr. Schlesinger, son of Joseph William and Mary Wagner Schlesinger, was born May 11, 1871, in New York City. Here he attended school and college, receiving from the College of the City of New York the B.S. degree in 1890, and from Columbia University the M.A. in 1897 and the Ph.D. in 1898. His doctor's thesis indicated the direction of his future career, for it was concerned with the measurement and reduction of photographs of the Praesepe group taken by Lewis Rutherford twenty years earlier.

His first astronomical position was in California. Here he established the International Latitude Observatory at Ukiah and remained there as the observer in charge from 1899 to 1903.

While in Ukiah he married Miss Eva Hirsch, who died in 1928. By this marriage he had one son, Wagner Schlesinger, now director of the Fels Planetarium of the Franklin Institute, Philadelphia, Pennsylvania. In 1929 he married the former Mrs. Philip Wakeman Wilcox, of New York City and Atlanta, Georgia, who survives him.

From 1903 to 1905 he was astronomer at the Yerkes Observatory. Here he carried through most successfully the determination of stellar parallaxes using photographic plates taken with the 40-inch telescope. This work was epoch-making and immediately rendered obsolete the heliometer method of finding stellar distances. The procedure he devised for the measurement and reduction of such plates is followed today by astronomers in this field of research with only slight modifications.

Stellar parallaxes continued to be one of his chief interests during all his life. When he became director of the Allegheny Observatory in 1905, one of his first tasks was to design a long-focus telescope for that observatory. This was a refractor especially constructed to do parallax work with a lens corrected for photographic light. With such a telescope the exposure time necessary for taking plates to find the parallax of a faint star is much shorter than is the case if such plates are taken with a visual refractor.

In 1920, when Dr. Schlesinger came to the Yale Observatory as its director, he immediately began planning the construction of another photographic refractor quite similar to that at Allegheny. This time the telescope was set up in Johannesburg, South Africa, where in 1925 the Yale Southern Station was established. As a result of the work done at this station the number of parallaxes measured for stars in the southern sky has been increased by over 1500; the information about the distance of the stars in the southern hemisphere is now nearly as complete as in the northern.

As a result of his work in this field, he published a catalogue of all known parallaxes, which has been and will continue to be of great use to all astronomers who for any reason need to know stellar distances. This catalogue contains parallaxes observed at various observatories reduced to a common system and gives the probable error for each parallax.

At Allegheny Observatory, he did much spectroscopic work, making a special study of spectroscopic binaries. He published several orbits, and devised new methods for finding these orbits. Among the interesting stars included in this work were δ Librae and β Persei. His final orbit for the latter was never published. As early as 1909 he observed in δ Librae the rotation effect which was later found also in β Persei and which now plays such an important rôle in the study of such stars.

In this period, from 1905 to 1920, Dr. Schlesinger laid the foundation for the work of determining accurate star positions by means of photography. He used a plate with an area of 25 square degrees and a camera designed by Dr. C. S. Hastings of Yale University. The images over this large field were excellent and the measures from a single plate gave positions comparing favorably with the best meridian positions. The measures were made on an engine using a long screw, designed by Dr. Schlesinger especially for this purpose. These positions measured at Allegheny were later published in the *Transactions of the Yale University Observatory.*

After he came to Yale, he used a camera with a wide-angle lens designed by Dr. Frank E. Ross. This type of lens gives excellent images over a much larger field. The plates finally used at Yale cover approximately 120 square degrees. While the general plan was to reobserve all the stars in the A. G. catalogue published about 40 years ago, he con-

centrated on the zones from +30° to —30°. Before he retired all the plates for this region had been taken and measured. At the present time six volumes have been published and these contain the accurate positions and proper motions for about 85,000 stars. It is hoped the remaining volumes can be finished and published before very long. These will make the number of star positions and proper motions approximately 141,000. The Yale Observatory with a relatively small staff has been able to produce these catalogues so rapidly because of Dr. Schlesinger's originality and ability in planning the work so the highest precision was achieved with the greatest possible economy of effort. Results were tested and errors eliminated, so that the catalogue positions were accurate, but no numerical computations were carried beyond the point where they had real meaning.

Dr. Schlesinger had a wide knowledge of astronomy in general and a special interest in the history of the subject. He contributed the chapter on astronomy to the two editions of "The Development of the Sciences" published under the auspices of the Yale chapter of Gamma Alpha.

He was closely associated with the growth of the American Astronomical Society, for he became a member in 1905, soon after it was founded, and was on the council from 1908 to 1928. During this period, he was successively second vice-president, first vice-president, and president. His presence at a meeting was always valuable, for his wide information, enthusiasm, and sound judgment made his frequent comments interesting and pertinent.

He took an active part in the work of the International Astronomical Union, being a member of numerous committees and attending the meetings regularly. He was one of the vice-presidents from 1925 to 1932 and president from 1932 to 1935. His sane outlook and wise counsel helped the progress of astronomical research in many ways both at home and abroad.

His scientific career brought Dr. Schlesinger many honors. He received an honorary degree from the University of Pittsburgh in 1920. He was made a member of the American Philosophical Society in 1912, of the National Academy of Sciences in 1916, and a fellow of the American Academy of Arts and Sciences in 1921. In 1929 he received the Bruce Medal from the Astronomical Society of the Pacific.

In 1925 when the International Astronomical Union was meeting at Cambridge, England, he received an honorary Sc. D. from that University. In 1914 he was elected a foreign associate of the Royal Astronomical Society, which in 1927 awarded him the Gold Medal and elected him the first Darwin lecturer.

The French Academy of Science gave him the Valz Medal in 1926 and made him a corresponding member in 1932. When the Interna-

tional Astronomical Union met in Paris in 1935 with Dr. Schlesinger as its president, he was appointed an officer in the French Légion d'Honneur.

Dr. Schlesinger was completely devoted to his science and also very conscious that the results of the present time owe much to the work of the past. He was anxious to pay this debt and to do his full share of work that would be useful in the future. In 1922, he made the need for better star positions the subject of his address as retiring president of the American Astronomical Society. His address was concluded as follows: "We may be sure that astronomers of our own day will fulfill in some way the obligations imposed upon them by the needs of their science, as fully and as unselfishly as have their predecessors." Truly it can be said of Frank Schlesinger that he did fulfill these obligations as fully and as unselfishly as any astronomer of the past or the present.

YALE UNIVERSITY OBSERVATORY, AUGUST, 1943.

The Physical Chemistry of Comets*

By P. SWINGS

In recent years considerable attention has been devoted by astronomers to the general problem of the relative abundances of the various atoms and molecules in celestial objects, in other words to their chemical constitution. The observational data are the intensities of the atomic lines and of the molecular bands present in the spectra; the next step is the interpretation of the observed intensities in terms of abundances.

The problem is especially interesting, but at the same time particularly difficult, in the case of the comets, and it illustrates in the most striking fashion, the usefulness of a close collaboration between astronomers, physicists, and chemists.

First, what are the observational data? A cometary spectrum consists of emission bands of molecules superposed over a solar spectrum, due to the reflection or scattering by the solid or gaseous particles present everywhere in the comet but especially abundant in the nucleus. The relative intensity of the solar spectrum and of the bright bands depends on the distance of the comet from the Sun. Comets observed at very large heliocentric distances have only revealed a solar spectrum indicating that they contain then relatively few gaseous molecules emitting in the observed spectral region. Yet a renewed, thorough investigation of this spectroscopic problem should be of primary interest in the light of the recent results on the polyatomic molecules of comets. At small heliocentric distances, not only do we find molecular bands, but even the yellow lines of the sodium atom appear.

*Address given at the May meeting of the Sigma Xi Chapter of the California Institute of Technology, Pasadena, California.

Considerable resemblance exists between the spectra of different comets. But even for comets having the same excitation, *i.e.*, observed at the same distance from the Sun, there may occasionally occur striking differences in the relative intensities of the solar spectrum and the emission bands, as well as in the relative intensities of the bands due to different molecules. This indicates that the comets do not all possess exactly the same chemical constitution.

What are the molecules identified in cometary spectra? Much progress has been made in the course of the last three years, and we have now the following list of identified molecules: OH, NH, CN, CH, CH^+, C_2, CO^+, N_2^+, CH_2, NH_2, and probably OH^+. All the strong emission features of comets are now identified, and further additions will require new observations in the red and infrared regions.

What is the mechanism of excitation of the emission bands of these molecules? Are they emitted as a result of electron collisions, or through some process of photodissociation by solar light, or as a pure fluorescence excited by solar radiation? It is possible to decide unambiguously in favor of the latter mechanism, *i.e.*, the pure fluorescence, in the following way. If a specific molecular line can be excited only in a wavelength coinciding with a strong absorption line of the solar spectrum, little energy will be available in the Sun for this particular excitation, and the corresponding cometary line will be weak or even absent. This is actually what we observe: for example, the cometary bands of cyanogen have a very peculiar, irregular intensity distribution, unlike anything obtained in a laboratory discharge. On the other hand, the cometary band structure can be fully explained on the basis of a fluorescence excited by the complex solar radiation. Physicists will undoubtedly correlate this observation with the complex superposition of resonance doublets observed in the laboratory fluorescence spectra of diatomic molecules, such as I_2, Br_2, S_2, Se_2, Te_2, etc., when they are excited by non-monochromatic radiation. And indeed the two observations are essentially identical, except for the fact that densities are so low in comets that we never have to fear collisional effects! Actually most cometary molecules live their whole life, until photodissociation or photoionization occurs, without encountering a single collision.

At first sight it might seem strange that a low temperature object, such as a comet, may contain molecules like CH, NH, OH, etc., that are not considered as chemically stable. But this is, of course, due to the low densities, prevailing in comets. Once a CH radical has been formed by photodissociation of a more complex chemically stable molecule, it will not have the slightest chance to re-combine in a collisional process.

How do these chemically unstable molecules originate? The gaseous atmosphere of a comet is formed by the liberation of molecules which were occluded in the solid particles. These parent molecules must of

course be chemically stable compounds. From the observed emission bands we gather that the following occluded compounds must be present in the cometary solids: H_2O, NH_3, CH_4, C_2N_2, N_2, CO or CO_2. Although this is about all that we can say with any degree of confidence at the present time, it seems rather tempting to relate the cometary problem to the chemical constitution of the occluded gases found in meteorites by heating or breaking them in vacuum. We know that meteorites also reveal CH_4, CO_2, N_2, etc. It might not be entirely legitimate to identify the two types of objects; yet a comparison is very useful. It is well established, for example, that the occluded gases of the stone and iron meteorites do not have the same chemical compositions. As a working hypothesis we may thus at least consider that the differences between individual comets might be related to the differences between meteorites.

The different types of molecules have very different distributions in a cometary atmosphere. Whereas CH, CH_2, and NH_2 are concentrated very near the nucleus, OH extends farther out, NH still farther, and CN and C_2 are found all over the head. The ionized molecules are found especially in the tail, up to very large distances from the nucleus; yet in the head, they are found only very close to the nucleus. The extension of a molecule is of course the product of its average velocity by its average lifetime. Some molecules such as CO^+ and N_2^+ have very small initial velocities, but extremely long lives; others, such as CH or C_2, have large velocities, and intermediate cases are also observed. The initial velocities cannot be due to thermal agitation, since molecules of nearly the same mass, such as CN and CO^+, have very different initial velocities. Hence these velocities must result from the photodissociation of the parent molecules.

As for the average lifetime of a specific molecule before photodissociation or photo-ionization occurs, this depends not only on the physical characteristics of the molecule but also on the solar energy available in the spectral region considered. For example, if the CO^+ and N_2^+ ions are produced by the photo-ionization of CO and N_2, the solar radiation required lies beyond λ 900 A, *i.e.*, beyond the Lyman limit. We do not know how the Sun radiates in this spectral region. But we do know that practically all the hydrogen atoms are in their ground state in the solar atmosphere; hence the Lyman absorption lines, and the Lyman absorption continuum must be extremely strong. As a result we may have to think of other possible mechanisms of formation of CO^+ and N_2^+, such as photodissociation of parent molecules into a positive and a negative ion, or photo-ionization in several steps via intermediate levels, or ionization by impact of solar electrons.

To discuss in detail the physico-chemical problems of comets we need: additional laboratory or theoretical data on the oscillator strengths of the abundant molecules; physico-chemical information on the dissociation and ionization properties of these molecules; more precise data on

the lifetimes of molecules in their rotational and vibrational levels; also further study of the gases occluded in meteorites.

The collaboration of physics, chemistry, and astronomy has already given gratifying results in the interpretation of cometary spectra. But it is only a beginning; in this field we are still in the pioneering stage!

May 4, 1943.

The Origin of the Lunar Craters
(A Summary)

By ROY K. MARSHALL

Introductory

Because of several references to a brief report which I gave before the 66th Meeting of the American Astronomical Society at the Yerkes Observatory in September, 1941, it has seemed useful to seek publication of the full paper which was orally abstracted at that time. At the meeting, the abstract was prefaced with the statement that nothing original was being presented; instead, what I had to say was in the nature of an integration of several scattered ideas which had appeared in various places at various times, but which seemed to be a part of the same picture. While I firmly agree with the statements of those whose work I here combine, I deem it only fair that the original papers cited should be examined by those who wish to challenge the ideas presented. My part is that of reporter and coördinator. It might be added here that much additional material confirming the ideas here expressed has appeared in the past year and a half, but none of this has been incorporated in the paper.

In textbooks and popular discussions of the origin of the lunar formations there is a degree of preference, or at least a lack of dislike for the meteoric impact hypothesis which is hardly in keeping with oft-reiterated facts. Because these ideas which negate the impact theory are in widely scattered places, it seems wise to put them together, to see what the result will be.

We find in some textbooks the most amazing statements which attempt circuitously to destroy any confidence in an igneous theory at the very beginning. For example, Forest Ray Moulton has this to say ("Astronomy"; The MacMillan Co., 1931):

> "It is perhaps unfortunate that the term 'crater' is applied to the lunar features. . . There are no clear indications of lava flows or erupted cinders, and often the rims and surrounding scattered materials would not fill the crater depressions. . . The steep and crumbled walls of the lunar craters indicate that they were produced by extraordinarily violent forces. . . As has been remarked, millions of meteors rain daily upon its mountains, plains, and craters, which are wholly unprotected by water or an atmosphere."

Similarly, H. Spencer Jones says this ("General Astronomy"; Longmans, Green, and Co., 1923):

> "The term 'crater' suggests a volcanic origin, and is, on that account, perhaps as unfortunate and misleading as is the description of the dark areas as seas. One theory of their formation does, however, attribute them to volcanic origin. It is supposed that many years ago matter was ejected from the central mountain and that this matter gradually piled up and formed the outer ring. . . Signs of lava flows on the Moon which might have been anticipated from the violence of the supposed disturbance, are almost or entirely lacking."

Robert H. Baker ("Astronomy: An Introduction"; D. van Nostrand Co., Inc., 1930), while leaning heavily toward an igneous origin, says this:

> "The chief objection to the volcanic hypothesis has been the disparity in size between explosive terrestrial volcanoes, such as Vesuvius, and the lunar craters."

Most objections to igneous activity for the origin of the craters are based perhaps upon a too-close scrutiny of and adherence to the model of the conventional type of terrestrial volcano. There have been several rather wild forms of vulcanism suggested, as well, and because there were rather violent objections to them, all forms of vulcanism have been condemned. Too often have the old ideas been mingled with the new, to produce a strange hodge-podge which can be accepted neither by astronomers nor by geologists. As something of an example, in a recent report of the Committee on Study of the Surface Features of the Moon[1] there is the statement that "lunar craters are cleaned out, as a rule, and thus are of the nature of immense deep holes in the ground . . ." How true this may be we shall see presently, but at first glance this seems to hark back to the old Nasmyth-Carpenter idea of a central hole spouting ashes and lava which fell 20 or 30 miles away to form the ring of the crater. The Committee has concluded that volcanic activity is responsible for the formations, and in discussing the rays which emanate from Tycho and other centers it is stated that, to produce the longest (1500 miles) rays on the Moon, an angle of ejection of 26° and an initial velocity of 0.92 mile per second would be required. Such velocities have been observed in the volcano Cotopaxi in Ecuador. Moreover, Jerome Alexander[2] says, "Professor Wilbur A. Nelson calculated that during the Cretaceous period a now-extinct volcano in Kentucky spat up 50 cubic miles of lava, whose fall may be traced 800 miles north and south, and 450 miles east and west of the crater." Thus, while the exact composition of the lunar rays may remain unknown, there is no doubt that they could have been formed by volcanic ejection. But they may be the only evidence for any conventional "explosive" vulcanism similar to the type of activitity best known on the Earth.

Certainly no one who studies the Moon for even a short while can

[1] *Science News Letter*, March 1, 1941.

[2] *Science*, **94**, 154, 1941.

doubt that there are to be seen there many evidences of some form of volcanic activity. The lunar "seas" are almost too obviously lava plateaus. Professor Reginald A. Daly (Department of Geology, Harvard University) thus describes the formation of such a lava flow: "A tectonic earthquake fractures and fissures the crust, and from the basaltic abyss, 30 or 40 miles beneath the crust of crystalized rocks, the glassy basaltic lava gushes out." On the Earth, there exist great basaltic plateaus in North America (200,000 square miles), in Brazil and Argentina (300,000 square miles), and in the Dekkan of India (200,000 square miles). It is quite common on the Earth to have, at points along the fissure, volcanoes, as in the 500-mile-long string in Java, and the 1200-mile-long Hawaiian chain. So on the Moon, Daly points out what he believes to be such a fissure-chain in west longitude 60°, consisting of Pontecoulant, Fraunhofer, Furnerius, Petavius, Vendelinus, Langrenus, Webb, Apollonius, Mare Crisium (the deepest lunar walled plain), Cleomedes, Bernoulli, Messala, and Schumacher. The lunar maria are almost certainly great lava plateaus.

The statement quoted from the Committee on Study of the Surface Features of the Moon, "lunar craters . . . are immense deep holes," is not a very good description of any but the smallest craters. The crater Copernicus might be considered typical of the larger objects. It is 56 miles in diameter, and it stands on a gently sloping elevation about 170 miles in diameter. In passing, we note that such a formation is in no sense to be explained by hypothesis of impact. The walls rise 11,000 feet above the floor, so the depth is but 1/27th of the diameter of the crater. Certainly such a formation is immense, but as compared with its diameter its depth is very slight.

An investigation of lunar crater diameters and depths reveals the fact that, contrary to general opinion, there is a good correlation between the two measures. Lunar craters must in general be labelled shallow. From careful measures of about 100 craters, ranging from 10 to 93 miles in diameter, the relation

$$h = 0.298\ d^{\frac{1}{2}}$$

has been derived; in this, h, the height of the walls inside, and d, the diameter from crest to crest of the walls, are expressed in miles. To express the height in feet and the diameter in miles requires multiplying the right-hand side by 5280, and the result is

$$H = 1573\ d^{\frac{1}{2}}.$$

The average residual in H, for the craters used to form the relation, was about 200 feet. For a specific example, the value of h is 2.23 miles, or H is 11,773 feet, for Copernicus, with a value of d equal to 56 miles. We have already seen that the measured value of H is 11,000 feet, so the error is about 7%.

Certainly this feature of shallowness is a serious objection to any hypothesis of meteoric impact. The best terrestrial example of an im-

pact crater, near Winslow, Arizona, is 4150 feet in diameter and is at present (after 50,000 years, at least, of filling and erosion) about 570 feet deep. This ratio of depth to diameter of at least 1 : 7, when the crater was new, makes this object quite different from any except perhaps the smallest lunar craters. At all events, it is intuitively very difficult to imagine an impact crater which is 100 miles or more in diameter, yet only 2 miles deep. Surely, in order to disturb the surface for a radius of 50 miles, a projectile would need to penetrate to a depth of at least 12 or 15 miles. The very pat explanation to be advanced by those who favor the impact hypothesis is that lava released by the explosion has filled the craters' bottoms. But exact measures of contours show that crater floors are seldom horizontal.

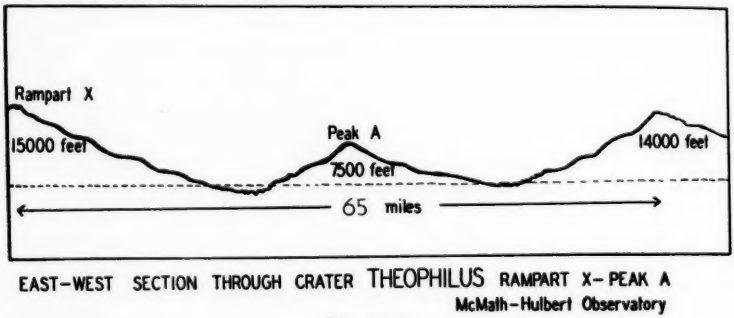

FIGURE 1

Despite the apparently level floor of Theophilus, this cross-section shows that none of it is flat. However, the vertical scale is extended, as compared with the horizontal, by a factor of three, in this figure.

But perhaps the most cogent argument against the impact hypothesis has to do with our failure to observe any impact phenomena on the Moon today. Perhaps we should not expect to see new large craters formed, but the energy made available when even a small meteoroidal body is halted suddenly is tremendous. It has been computed by Moulton[3] that the rate at which work is done per square inch of meteoroid entering rock at a velocity of 20 miles per second is 2×10^{10} horsepower, equivalent to 3.57×10^{12} calories per second. The Sun's emission is but 9650 calories per square inch per second; a hemisphere of the Sun radiates about 4.5×10^{25} calories per second, approximately 1.27×10^{13} as much as the rate of work of the crashing meteorite. This is equivalent to a difference of 32.7 magnitudes, and since the Sun's light would be of magnitude —40 if it were at the Moon's distance, a 1-inch meteoroidal body falling on the Moon with a speed of 20 miles per second, delivering up all its kinetic energy in the form of visible light, would produce a flash which *seen from the Earth* would be of

[3] *Publications of the American Astronomical Society*, **6**, 372, 1930.

magnitude —7. The velocity used is not far from the average with which such bodies approach the Moon, but it is quite unlikely that all the energy would be available in the form of light; if we reduce this to only 1%, however, we still have a flash of magnitude —2.

La Paz[4] has determined, on the basis of reports of the 1908 Siberian meteoritic explosion, that a 100-pound meteoroid would produce, upon impact with the Moon, a flash of magnitude —1, a value not inconsistent with that in the foregoing paragraph. Certainly, then, a 10-pound meteoroid would produce a visible flash, as it struck an airless Moon and delivered up its energy. Now C. C. Wylie states that about 6000 meteoroidal bodies of mass 10 pounds and more enter our atmosphere each year. Since to a very close approximation only the relative areas (and not the masses) of the Earth and Moon need be considered when comparing the relative number of meteoroids swept up by the two bodies, and the areas are as 1 :13.4, the Moon should suffer about 450 impacts (*i.e.*, from meteoroids of mass 10 pounds or more) per year, for its total surface. On the average, a quarter of the Moon's total area is seen dark, so at least 100 would be seen to fall on the dark portion of the Moon's visible hemisphere, each year. Even if we conservatively estimate the brightness as of magnitude 2 or 3, surely one each 3 or 4 days would not have escaped detection during the past century of more or less intensive study of the Moon; during this period, at least 10,000 impacts on the dark portion of the Moon must have occurred, if the Moon has no atmosphere, and the flashes would certainly have been observed. Perhaps we may put it this way: If these flashes are not to be expected, there never was a body large enough to produce a crater on the Moon.

Since we know that such meteoroids enter the Earth's atmosphere, the Moon must be getting its share, but it is obvious that they do not strike the surface of an atmosphereless Moon, for we do not see them. Is there, then, a lunar atmosphere which destroys most of the meteoroids, and so reduces the velocities of the others that they produce no conspicuous flashes upon impact with the Moon's surface?

Such suggestions have been made in the past, but they have been overlooked or deliberately ignored. W. H. Pickering (in *Astronomy and Astrophysics*) as early as 1897 suggested a lunar atmosphere, and he inserted the same idea in his book, "The Moon." In 1921 (in *Nature*) and later (in "Splendour of the Heavens"), the late A. C. D. Crommelin stated that there might exist undetected a lunar atmosphere such that the density at a height of 43 miles above the surface of the Moon would be equal to that at the same height above the Earth's surface. Inasmuch as meteors appear on the average at heights of 80 miles and disappear at about 40 miles, in the Earth's atmosphere, such an atmosphere on the Moon would be quite effective in consuming most meteors.

[4] *Popular Astronomy*, **46**, 277, 1938.

Consider for a moment what the consequences are. Meteors as bright as —4 or —5 are rather common, in the Earth's atmosphere. Such a meteor in the hypothetical Moon's atmosphere would be of magnitude 13 or 14, as seen from the Earth, and would easily escape detection. For each million square miles of the Earth's surface, there is about one meteorite fall per year; the visual accompaniment of such a phenomenon is of magnitude —10 or —12, as an average guess from the confused reports of many such falls. Such a meteor on the Moon would appear from the Earth to be of magnitude 6 or 8; the area of the Moon's visible surface is 7,350,000 square miles, so there would be one such meteor each 50 days or so, or, for the dark portion only, one each 100 days, and the chance of an observation of this kind is rather small.

Thus the absence of observed explosions of magnitude 2 or 3 (to be conservative) each 3 or 4 days, as would occur on an airless Moon, seems to demand an atmosphere there; the absence of observed meteor trails of magnitude 6 to 14, each week or month, does not argue against the presence of such an atmosphere.

But it is the common impression that theory demands that the Moon shall have lost any primitive atmosphere it may have possessed, and occultations and other observed phenomena agree at least to the extent of permitting no atmosphere of density greater than about 10^{-4} that at the Earth's surface. It is a common error to apply in the theory a temperature of about 400° K as that for the layer from which molecules are escaping from the Moon, but it is doubtful if the surface temperature of the Moon should be used, any more than that the surface temperature of the Earth can be taken as the temperature of the Earth. At some level far above the surface, temperatures of the order of 250° K prevail, for the Earth, and, lacking more specific information, we may suggest that a similar temperature be adopted for some layer in the Moon's atmosphere; to a first approximation, only the relative values of surface gravity of the Earth and Moon (1:6) need be considered.

As Jeans has shown,[5] for the complete dissipation of an atmosphere of the Moon within 10^9 years, a temperature of 418° K is necessary for carbon dioxide, 304° K for oxygen, and 266° K for nitrogen. Perhaps this last gas has completely escaped, but one must be very pessimistic to state that all of the oxygen and carbon dioxide have left the Moon. While there may be other gaseous constituents on the Moon, not occurring in the Earth's atmosphere, we need hardly call on them in order to cloak the Moon with a sufficient layer of atmosphere, as we shall see in the next few paragraphs. At all events, the rate of depletion of the Moon's atmosphere now must be very slow, and we must not forget, too, that unless the Moon is very cold even to its very center, there

[5] "Dynamical Theory of Gases," Cambridge, 1925.

will be gaseous elements escaping to the surface; too, many meteors, whether consumed or not, will release large quantities of occluded gases, so perhaps the atmosphere is growing as fast as it is being depleted.

There is no doubt that the surface density of the lunar atmosphere is low; observation will not permit it to be more than 10^{-4} that at the surface of the Earth. Doubtless, too, the density of the lunar atmosphere diminishes as we consider points at great heights above the surface of the Moon. The crucial factor is this, however: Low surface gravity produces a thin atmosphere, but at the same time the density gradient is low.

For years the twilight arc of Mars has indicated an atmosphere of considerable extent, yet the density at the surface of Mars is very low. At a height of 20 miles, however, the atmospheres of the Earth and Mars are probably not very different. At the other extreme, there are being found today white dwarf stars with surface gravities of the order of 3,500,000 times that of the Earth (for example, AC + 70° 8247), and the statement has been made and accepted that the "atmosphere" of such a star must be perhaps only a dozen feet thick, thus accounting for the absence of absorption lines in the spectrum. High surface gravity induces high density gradient in an atmosphere, but for the Moon the low surface gravity must cause a low density gradient.

The lack of information concerning the actual densities and temperatures in the Earth's atmosphere is somewhat discouraging, but a statement often used is that the density of the Earth's atmosphere diminishes by one-half, for each 3½ miles of ascent from the surface. To a first approximation (omitting the factors of temperature and composition), because the Moon's surface gravity is but one-sixth that of the Earth, the lunar atmosphere will diminish in density by one-half for each 21 miles of altitude. No matter what the density of the lunar atmosphere may be (other than precisely zero!) at the surface, there will be some altitude at which the lunar and terrestrial atmospheres will have the same density; furthermore, above that altitude the density of the lunar atmosphere will be *greater* than the density of the Earth's atmosphere at equal altitudes. The following table displays approximate values of these critical heights, for various values of the density of the lunar atmosphere at the surface, in terms of the surface density of the Earth's atmosphere. Almost any type of refinement of the computation tends to decrease these heights (*viz.*, Crommelin's height of 43 miles, which corresponds with the value 56 miles in the table), hence to increase the effect of the lunar atmosphere.

Surface Density	Height of Equal Density
10^{-4}	56 miles
10^{-5}	70 miles
10^{-6}	84 miles

On the Earth, the average meteor path extends from about 80 to 40 miles above the surface. The densities involved depend on the one who determines them, but perhaps we may say that they are within the range 10^{-10} to 10^{-5}; for any of the assumptions of the surface density of the lunar atmosphere, meteors would become luminous at heights far in excess of those at which meteors become luminous in the Earth's atmosphere. On the Earth, a meteor requires 1 to 5 seconds to traverse its 25 to 100 miles of air path. On the Moon, the path would be much longer, and the meteor would be, if anything, more certain to burn out than it would be in the Earth's atmosphere.

Despite a certain lack of precise values for several of the parameters, it certainly is no stretch of the possibilities that the Moon is possessed of an atmosphere which is capable of destroying meteoroidal bodies which enter it. It seems doubtful that the Moon possesses any more meteorite-formed craters than the Earth.

If, then, the craters are not the results of impacts, how are we to explain them? Surely not by the old "fountain" idea of Nasmyth and Carpenter, whereby a central cone spouted material out to a distance of 20, 30, or even 60 miles, in all directions, to build up the crater ring. But even this is more reasonable than the impact hypothesis! We should not adhere too closely to the forms of volcanic manifestation now observed on the Earth, for it is fairly certain that the types of activity we see here are practically the tag-end of the igneous activity of the Earth, as was pointed out by the late H. G. Tomkins.[6]

Certainly the presence of the maria and of the many "drowned" craters on their floors, as well as the several Wargentin-like formations (craters filled to the brim), indicates the presence of lava flows. As additional evidence we have such craters as Archimedes and Aristillus, in which we find breached walls, through which something flowed out onto the plain outside. The non-uniform distribution of the areas of greatest disturbance has often been mentioned as additional evidence that internal forces were responsible for the observed features.

One interesting type of terrestrial igneous formation is the laccolith. They are not well known, and are considered by some to be almost mythical, for they were formed slowly, and erosion almost kept up with their rate of formation, and it is impossible, today, for example, to photograph a laccolith on the Earth. Only geological prospecting reveals the presence of such "intrusions by channels (usually several) from below, up which the molten magma was forced under the solid crust of the Earth, the latter being upheaved by the accumulated lava without being broken, and forming a dome of great size full of molten material, which later cooled and solidified" (Tomkins). In historic times, in Iceland, in addition to lava plateaus, there have been formed vast domes pushed up to heights of 4000 feet, with diameters of 17

[6] *Journal of the B.A.A.*, **37**, 161, 1927.

miles. In an ancient laccolith discovered by G. K. Gilbert in the Henry Mountains of southern Utah, a layer of the crust 10,000 feet in thickness was pushed up to a height of 3000 feet above the plain. Incidentally, if we should count all these and other forms of volcanic activity, in the opinon of Gilbert, we should find that the number now existing would indicate, contrary to popular belief, that the Earth has suffered as much as has the Moon from igneous action. The Moon's surface is timeless, in the sense that both old and new features remain, side by side, without the erasure which occurs on the Earth, due to the dense atmosphere, with its water vapor.

Again to quote Tomkins, "Consider what might have happened in the case of a laccolith which, originating on the Moon in a way similar to those on the Earth, instead of solidifying, continued (as some of those on the Earth doubtless did) to force up more and more molten magma, and further and further to uplift the lunar crust. The result would be that the crown of the dome would not eventually burst like a bubble, but fissure comparatively quietly, owing to pressure from below, thus allowing the top of the dome to fall piecemeal into the lava within, where it would probably melt or eventually be deposited on the floor. Until pressure was relieved, the dome itself from the base would continue to rise, and also, of course, to extend, and the lava with it, cracking and melting the edges at the top, and forming a lava lake which, as time went on, would grow larger and larger and bring down the overhanging walls, until they had practically all fallen in. At length a stage would be reached at which equilibrium would be established, and after that, as we see in the Hawaiian craters and others still on the Earth, only on a larger scale corresponding with the greater action at the time, the lava lake would subside, and in the end would leave a floor depending for its size on the extent of the upheaval, and for its form on the extent of the retirement of the molten magma, either above, equal to, or below the original level of the crust according to the extent of the evacuation. . . The formation would be hollow, and the result ring-shaped in form and not a solid cone. . . Central peaks, smaller craters or craterlets . . . would follow from the nature of the laccolith from which the formations themselves arose. . . A central peak would no doubt arise from the central pipe in case of a subsequent minor eruption if the pipe were still open or not firmly closed by cooling. If there were more pipes than one, more peaks would be caused in the same way." Goodacre suggested that perhaps a single peak in some instances was shattered by an explosion when the activity had almost come to an end.

To clinch this argument, we find laccoliths on the Moon. There are two near Arago, two others near Linné, many in the neighborhood of Hortensius and Milichius (east of Copernicus), some in and near Darwin, and one east of Kies. Some are low and barely discoverable; others are high. Some are smoothly rounded, others have the beginnings

of crater pits in their summits. Careful study will probably show a complete sequence of these formations, ranging from the lowest of elevations to craters half-formed.

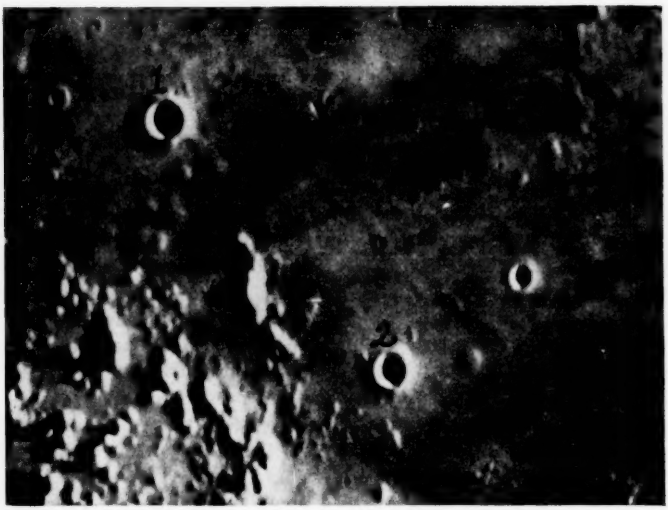

FIGURE 2

Photograph taken at the Mount Wilson Observatory showing Laccoliths in the Vicinity of Hortensius (1) and Milichius (2). Within 150 miles of this region, at least a dozen other Laccoliths are to be found.

Until the laccoliths and Wargentin-like craters are otherwise accounted for, it would seem that we must consider the igneous theory of the origin of the lunar craters, as outlined by Tomkins, to be the true one. The hypothesis of meteoroidal impact must be considered seriously challenged because of the failure to observe impact phenomena on the Moon today, probably due to the presence of a thin, but effective, lunar atmosphere.

FRANKLIN INSTITUTE, PHILADELPHIA, PENNSYLVANIA.

Copernicus and Science; from Yesterday until Tomorrow*

By HARLAN TRUE STETSON

The manuscript of this paper arrived after the forms of the special Copernican Quadricentennial Issue (June, 1943) were closed. However, since the commemoration of events which occurred four hundred years ago need not be limited too closely as to time, this paper is still timely. We, therefore, give it here as a part of the Copernican literature which this year has brought forth. ED.

Tonight all Poland lies smouldering beneath the most devastating destruction that has ever invaded the continent of Europe. Its universities have been closed, its museums and libraries looted of the treasures of centuries of civilization of which the Poles and the civilized world could be justly proud. But the scholarship of Poland has not died. Polish statesmen, scholars, and scientists dot the territories of the United Nations as the struggle for the survival of culture and learning goes on with the assurance of ultimate victory.

Tonight we celebrate the 400th anniversary of the death of Poland's greatest man of all time, Nicolaus Copernicus. The significance of this man in the world of science has been known throughout the centuries and has spread with the spread of civilization over the entire globe. His greatness lay not so much in the enunciation of an astronomic theory but rather in the comprehensiveness of the idea that was destined to revolutionize the astronomical and even the philosophical and religious thinking of all mankind.

If, as it is often said, the greatest truths are those that can be most simply expressed, then the contribution of Copernicus can, indeed, be stated very simply: "He stopped the sun and set the earth in motion."

It is always embarrassing to survey the long list of true notables that have contributed to the progress of science in the world's history and to give any small number as preeminently outstanding. Yet, if I were called upon to select three names, I should say, without much hesitation, Copernicus, Newton, and Darwin. These three have certain characteristics in common that make them inseparable in the triumph of progress. These characteristics are imagination, the boldness of genius, and an originality exhibiting extraordinary comprehensiveness of the concept. Of the greatest of these, all things considered, I believe the laurels would go to Copernicus, for it was he who laid the fundations of modern

*Based upon an address given at Brown University, May 20, 1943.

astronomy without which Newton could not have built his law of gravity, and he opened the gates to a revolutionary type of thinking challenging the orthodox which had to take place before the doctrine of evolution could gain a foothold in our thinking.

While we are assembled to laud the achievements of this great man, some cynically minded critics may well remind us that Copernicus was not the first to promulgate the idea that the earth travelled about the sun and not the sun about the earth. Before the beginning of the Christian era such Greek scientists as Pythagoras, Aristarchus, and Hipparchus had taught a heliocentric theory, but that was before the crystallization of a geocentric philosophy that remained sacred for 1500 years; sacred to scholars and sacred to the church.

The quality of Copernicus that makes him preeminent in astronomy was his boldness in championing truth in place of orthodoxy and spending a lifetime in accumulating evidence for his convictions. In the vernacular of the diamond he was the first to go to bat for an idea which had lain dormant since the ascendency of Greek science.

To appreciate something of the revolutionary character of such a conception, it is necessary for a moment to take a look at the philosophy of the pre-Copernican era.

It was Claudius Ptolemy, who lived in Alexandria and thrived around 150 A.D., that was responsible for dominating astronomical thinking for nearly 1500 years. After weighing the pros and cons of an earth-centered against a sun-centered universe, he adopted the former and endeavored to explain the complicated motions of the planets by a system of epicycles. The Ptolemaic system rested so obviously upon the natural appearance of the starlit sky that it was easily adopted by the thinking and the unthinking. Nature has a curious way of hiding her complexities. Man has always been baffled by the confusing problems of relative motions. If the motions of the planets were such as to make their future positions almost unpredictable, nature made them so.

The explanation to the primitive mind was an all-wise Deity who did things that way, thus shutting off the pursuit of curiosity for the detailed workings of a plan. Since Deity explained all nature, the more simple and obvious the conception the more easily could one's theology be adopted to the universe. The starlit heaven became his throne and the earth his footstool. On such a geocentric system of astronomy, medieval theology could flourish. It is only when we consider this background and the whole impact of its consequent theology upon medieval civilization that we can appreciate at all the catastrophe to thinking that came about with the publication of *De Revolutionibus*. It must be remembered that it was Copernicus' observations and his astuteness of mind in rationalizing data that gave increased evidence in support of his heliocentric theory.

It will be remembered that it was the retrograde motion of the planets

that had presented the greatest difficulty to the astronomers and had caused the invention of the epicycle. Not only did the heliocentric hypothesis solve the problem of the retrograde motion far more simply, but it carried with it other astronomical implications that sooner or later must needs be verified. One of these was that the planet Venus should show phases like the moon and the other was that the remotest stars should show some small annual change in direction or parallax, due to the changing position of the earth in its orbit as it travelled about the sun.

These objections were real and were raised by the intelligent among the critics of Copernicus. Copernicus recognized these dfficulties and answered them wisely. In the one instance, "God was good and some day he would show the phases of Venus to someone," and in the second instance that the fixed stars were probably so far away that the motion of the Earth in its orbit rendered any apparent change in position undetectable by the instruments of that day. Astronomers will recall that it was nearly 300 years after the death of Copernicus when the discovery of the first parallax of a fixed star, that of 61 Cygni, was made known in 1840.

With one sweeping stroke the chief function of epicycles was cast aside, but the doctrine of the geocentric theory was not so easily to be deposed. That which had taken root in medieval scholasticism sacred with the authority of fifteen centuries was not so easily to be deprived of its heritage. Theology and ecclesiasticism had been inseparably entwined about an earth-centered cosmology. So heterodoxical an idea as a sun-centered system was not to be acclaimed without a long and bitter struggle. This was the dark cloud that overshadowed Copernicus.

His celebrated book which was brought to him from Nuremburg as he lay upon his death bed (May 24, 1543) was prefaced by a most conciliatory and diplomatic dedication to his Holiness, Pope Paul III. An appeal to the Pope shows the anxiety in Copernicus' mind over the difficulties he anticipated. This preface is so classic in science that it may well be quoted:

> "I can well believe, most holy father, that certain people, when they hear of my attributing motion to the earth in these books of mine, will at once declare that such an opinion ought to be rejected. Now, my own theories do not please me so much as not to consider what others may judge of them. Accordingly, when I began to reflect upon what those persons who accept the stability of the earth, as confirmed by the opinion of many centuries, would say when I claimed that the earth moves, I hesitated for a long time as to whether I should publish that which I have written to demonstrate its motion, or whether it would not be better to follow the example of the Pythagoreans, who used to hand down the secrets of philosophy to their relatives and friends in oral form. As I well considered this, I was almost impelled to put the finished work wholly aside, through the scorn I had reason to anticipate on account of the newness and apparent contrariness to reason of my theory.
>
> "My friends, however, dissuaded me from such a course and admonished me that I ought to publish my book which had lain concealed in my possession not only nine years, but already into four times the

ninth year. Not a few other distinguished and very learned men asked me to do the same thing, and told me that I ought not on account of my anxiety, to delay any longer in consecrating my work to the general service of mathematicians. . .

"I do not doubt that clever and learned men will agree with me if they are willing fully to comprehend and to consider the proofs which I advance in the book before us. In order, however, that both the learned and the unlearned may see that I fear no man's judgment, I wanted to dedicate these, my night labors, to your Holiness, rather than to any one else, because you, even in this remote corner of the Earth where I live, are held to be the greatest in dignity of station and in love for all sciences and for mathematics, so that you, through your position and judgement, can easily suppress the bites of slanderers, although the proverb says that there is no remedy against the bite of calumny."

We know that the printing of the book fell into the hands of Osiander who, realizing the highly revolutionary character of the proposed theory and the certain opposition that would be aroused, wrote a foreword in which he declared that the geocentric system after all was to Copernicus but an interesting hypothesis and an alternative method for explaining planetary motion. Probably this account of Osiander was responsible for the fact that the book survived at all. A ban was not placed upon the book until 1616 and it was not removed from the forbidden list of the church until 1835.

The next outstanding contributor to the establishment of the Copernican theory was Tycho Brahe whose astronomical career may conveniently be dated from the appearance, in 1572, of a new star in the constellation of Cassiopeia. This directed his interests to astronomy. Oddly enough Tycho Brahe never adopted the heliocentric hypothesis, but worked out a compromise theory which allowed all of the planets but the earth to revolve about the sun and restored the sun to its conventional place as a satellite of the earth. Thus he established a sort of league of planets idea with the earth not participating.

The Tycho system seems to have gained few adherents but he devoted himself to the most painstaking observations of the planets. These he made with new and improved instruments at his observatory on the Island of Hveen off the Danish coast. They gave the accumulating material necessary for his successor, Kepler, to establish the fundamental, though empirical, laws of planetary motions based upon Copernicus' conception of the solar system.

It was these fundamental laws of Kepler that made possible the work of the master mind of Newton in developing the law of gravitation by means of which, if given the positions of the planets at any given time and their motions, it was possible to predict with mathematical accuracy the positions for all subsequent time. With the publication of Newton's epoch-making "Principia" in 1727, the Copernican theory could be considered as having been definitely established, however iconoclastic were its implications.

One must not forget, however, an additonal contributor that re-

mains as an outstanding figure in the conflict of science with the ecclesiastical regimentation of the era. That one is Galileo. Galileo, rightly termed the father of experimental science, was the one who defied the laws of Aristotle and performed the classic and dramatic experiment at the leaning tower of Pisa which showed that heavy and light bodies fell from the top of the Tower to the earth with the same rapidity, whereas Aristotle had declared that bodies fell with speeds in proportion to their weight.

It was Galileo who first introduced the telescope to astronomy and he was the first to see Venus pass through phases like the moon. With his little "optic tube" he found the four satellites of Jupiter, the first objective additions to the solar system. It was Galileo who introduced the idea of inertia and the correct conceptions of motion that laid the foundation of mechanics upon which Newton based his "Principia."

With the advent of the telescope to astronomy, the universe grew by leaps and bounds. One may pass with mere mention that unpleasant period of the persecution of Galileo by organized ecclesiastics and his enforced abjuration, with the thought that science at last was becoming triumphant in its fight against superstition, ignorance, and arrogance.

With Newton the problems of planetary motion may be said to have been solved, and opposition to the Copernican heliocentric doctrine thereafter to be in the decadent. New worlds, however, were awaiting discovery through the perfecting of the telescope especially in the hands of the Herschels. With Willam Herschel the era of sidereal astronomy began. A fitting link in this transition was the discovery of the first new planet, the planet Uranus, which was found by Herschel while scanning the heavens in 1781. It will be recalled that it was the subsequently observed irregularities in the motion of Uranus that made possible the prediction of a still more distant planet based on Newton's gravitational theory, and in September, 1846, the more remote planet, Neptune, was added to the solar system.

The discoveries with ever increasing optical power of the true nature of the Milky Way and the existence of star clusters and nebulae are now common knowledge. The introduction of the spectroscope in 1859 opened the way for the physical study of the stars, making possible not only the understanding of their constitution but also their motions along the line of sight; some approaching and some receding at incredible velocities. The revelations, through the huge telescopes at the Mt. Wilson Observatory, which concern the remotest spiral nebulae, globular clusters, and vast clouds of cosmic obscuring matter have shown the vastness and the complexities of the universe to which Copernicus pointed when he reduced the earth to the dimensions of a satellite of the sun.

Although the sun is surpassed a million times by stars of greater size and magnitude, the sun still dominates the solar system and it is

the radiation from this central body that makes all life possible upon our planet.

It is quite impossible in this short space to even adequately outline the many developments in sidereal astronomy and we return to the earth and the sun for a recapitulation of some of the important relationships that have resulted since the day when the relationship of these two bodies was of major concern in the Copernican era. Here in the study of solar terrestrial relationships science has made great strides. Here new investigations have opened up fields of which Copernicus could not have dreamed; the Earth's atmosphere has become alive with whirling ions, electrons, charged particles caused by absorptions of the solar rays. Auroral fires glow when, during periods of sunspot activity, the earth receives an abnormal bombardment from missiles emanating from the sun.

In the air high above us, one hundred, two hundred miles up, stratified layers of ions resist the penetration of electro-magnetic waves and turn back to earth radio communications whose quality and intensity depend upon the varying radiations in the sun itself. The science of electronics has been born and new implications arise in the cosmic realm that bring to earth realities of far subtler findings than could have been imagined in the days of Copernicus.

Variations in the sunspot cycle are reflected in magnetic changes in the earth itself and its atmosphere. Ozone is formed and unformed by the extremely penetrating radiations in the ultra-violet. Cosmic rays from inter-stellar space rain constantly with pentrating energy upon our planet opening new realms for the investigation of science in the pursuit of truth for truth's sake.

However much has been discovered in astronomy and the physics of the earth since the work of Copernicus heralded the dawn of the new day for science, we are but upon the threshold of what the future may hold in store. Already through the study of tree growth a biological cycle has been found to parallel the cycle in solar activity and it behooves us with open-mindedness and candor to examine every new evidence for unsuspected truth and to hold back any encroachments upon the hard-won freedom in the pursuit of science in its search of the unknown. We may well indeed congratulate ourselves that the centuries of opposition to the heliocentric hypothesis have faded into the past, but we should not rest too complacently upon the assurances of our freedom of thought won through trying years since the days of Copernicus. Liberty is found and kept at the price of eternal vigilance.

We see today the devastations and restrictions placed upon science by the perversion of technocracy in the hands of our enemies and we are today waging a war to prevent the inundation of culture and learning by the threatened regimentation of Axis-dominated countries. While with confidence we can look forward now to ultimate victory for the

freedom of speech in the pursuit of science in a new order that is to be established, we cannot afford to be unaware of insidious influences that may be at work even in our midst which could well encroach upon our own liberties while endeavoring to promote the future of science in our own country and abroad.

Probably most of us are aware that there has already been presented to the Senate of the United States a Bill for the Mobilization of Science.* While ostensibly this Bill is to make possible the future organization of science on a grander scale than has been possible through individual initiative alone, the implications suggest inhibitions that could be dangerous in the extreme in the free pursuit of science for science's sake.

The Bill includes the establishment of an Office of Scientific and Technical Mobilization which shall be administered by an Administrator to be appointed by the President of the United States and to serve at his pleasure; to authorize such administrator to formulate and promote scientific projects and programs, to assess scientific and technical developments with relation to the national welfare, to coordinate scientific facilities and personnel, to make and amend appropriate rules and regulations which shall have the force of law; to appropriate the sum of $200,000,000 to carry out the provisions of this proposed act and to provide maximum penalties of $5,000 and/or one year's imprisonment for certain infringements of the regulations that such an administrator may set up.

It is of course gratifying to learn in the declaration of policy of this Bill that "the Congress hereby recognizes that the full development and application of the Nation's scientific and technical resources are necessary for the effective prosecution of the war and for peacetime progress and prosperity . . ." It is less gratifying to note that "serious impediments thereto consist in the unassembled and uncoordinated state of information concerning existing scientific and technical resources; the lack of an adequate appraisal, and the unplanned and improvident training, development and use of scientific and technical personnel, resources, and facilities in relation to the national need; . . . the trend toward monopolized control of scientific and technical data and; . . . the absence of an effective federal organization to promote and coordinate . . . scientific and technical developments."

It is some two years since the organization of the National Defense Research Committee and the Office of Scientific Research and Development together with the National Roster of Scientific Personnel. The remarkable results to the war effort which have already been obtained thereby with the large expenditures of over $100,000,000 during the current year may well make one wonder as to the implications of the impediments cited. It is to be noted furthermore that the object of

*See *Science*, **97**, 407, May 7, 1943.

the Bill is not solely to aid in the prosection of the war but for "peacetime progress." If the passage of this Bill were to insure not alone for the war but continuing thereafter the federal control of all science, scientists, scientific institutions, and scientific funds, then perhaps a truer title for the document would be "a Bill for the Regimentation of Science."

Forgetting for the moment the three hundred years of controversy with organized religion which the promulgation of the heliocentric system of the universe engendered, one cannot but wonder if Copernicus had lived in an era of government regulation of science such as is proposed whether his work would have fared better.

One has only to recall the history of science to recount a few of the outstanding scientific developments due to private enterprise and genius that undoubtedly would not have been possible under any enforced program of regimentation in science had such existed. Would any governmental administrator with a board of technical advisers politically appointed have ever sponsored the revolutionary experiments of Galileo, the doctrine of the origin of the species as advanced by Darwin, or the germ theory of contagious disease and the technique of immunization developed by Pasteur? Would Morton and Warren, who with great difficulty introduced anesthesia against the prejudice of organized medicine, ever have been able to succeed in eliminating terror and pain from surgery if they also had been opposed by a Board with federal authority? Would the two bicycle mechanics tinkering with gliders and flying machines ever have obtained a government subsidy for their Kittyhawk experiments after the demonstrated failure of the Langley aeroplane which had been constructed under the Smithsonian Institution with a Congressional subsidy of $50,000? What board of experts politically appointed would have known how to evaluate these discoveries from out-of-the-way sources at the times when even colleagues and medical and scientific organizations looked askance upon the early stages of these developments?

When, in 1714, the British Government offered a prize of 20,000 pounds for a means of finding longitude at sea with an accuracy of one half of a degree, and James Harrison, a clever carpenter, in 1735 succeeded in solving the problem by the invention of the temperature compensated chronometer, would a regimented scientific body have been more speedy in the recognition of the ultimate recipient of the prize money than the British Admiralty who stalled over Harrison's invention because it was not the kind of a solution to the problem that occupied the categories of their thinking? When federal authorities regarded the dreams of Samuel Morse as fantastic when he sought congressional funds for the first telegraph line, would the inventor have made better progress under the investigation of such an advisory body than through his persuasive sincerity in gaining private capital?

Fortunately or unfortunately genius is a strange plant in the economy of nature. One cannot foresee the territories in which the germs of genius may sprout, nor can one produce the plant of genius by the mere application either of fertilizer or of the pruning knife. It is significant that many of the major discoveries of science have been made by individuals and not by organizations of science or scientists.

The first attempt to institute a federal scientific advisory body for the benefit of national welfare was the creation of the National Academy of Sciences by President Lincoln in 1863 at a time of a national emergency.

At the beginning of World War I and at the request of President Wilson the National Research Council was established to act as an advisory body in scientific matters pertaining to the national emergency.

It is to be emphasized that in the executive order this Research Council was "to survey the larger possibilities of science, to formulate comprehensive projects of research and to develop effective means of utilizing the scientific and technical resources of the country for dealing with these projects. To promote cooperation in research at home and abroad in order to secure concentration of effort, minimize duplication and stimulate progress; but in all cooperative undertakings to give encouragement to individual initiative as fundamentally important to the advancement of science."

The most significant new proposal of the Kilgore Bill not included in the executive order creating the National Research Council is "to make, amend, and rescind appropriate rules and regulations . . . which shall have the force and effect of law."

Moreover, it is to be observed that the proponents of this Bill request Congress to pass a law that shall transfer their law-making power so far as it concerns the future of science to an unknown Administrator without offering the benefit of knowledge of the kind of laws that such an Administrator proposes to set up.

There is no time when the interdependence of the sciences has been more keenly felt than at present. We have passed through an analytical period calling for high specialization which has perhaps resulted in over-departmentalization in science. Marked progress of science in the future will call for the synthesizing of knowledge from many branches of science; this will require cooperative effort. In this we have a right to expect more federal cooperation and support both nationally and internationally, but to expect scientists to subscribe to a Bill providing for laws and regulations for a future conduct of science without a detailed knowledge of what those laws and regulations are to be is to invite restrictions that might well thwart the future progress of science itself. Such is not the spirit of science or the spirit of those pioneers in advancing the frontiers of knowledge of which Copernicus was an outstanding example.

NEEDHAM, MASSACHUSETTS, MAY 26, 1943.

Marvelous Voyages—VIII
H. G. Wells' The Time Machine

By LAURENCE J. LAFLEUR

The Time Traveller has built a machine which can travel indifferently in any of the four dimensions, the three of space and one of time. The story opens with the Time Traveller arguing for the special nature of time, and demonstrating a miniature model of his machine. It is a "glittering metallic framework, scarcely larger than a small clock, and very delicately made. There was ivory in it, and some transparent crystalline substance.—It looked singularly askew, and there was an odd twinkling appearance about one bar, as though it was in some way unreal." When this lever is pressed one way, the machine glides into the future, the other way, into the past. Then the lever is pressed. "There was a breath of wind, and the lamp flame jumped. One of the candles on the mantel was blown out, and the little machine suddenly swung round, became indistant, was seen as a ghost for a second perhaps, as an eddy of faintly glimmerng brass and ivory; and it was gone!" When one of the guests objects that if the machine went into the future it should still be visible, and that if it went into the past it should have been visible the week before, the Time Traveller refers to the psychological threshold. The machine while travelling goes through any present so rapidly that it is not perceived by occupants of that present.

A little later the Time Traveller goes on his full scale machine. At ten o'clock one morning he sat in the saddle, pulled the starting lever, and immediately after the stopping one. In a second the clock was reading half past three. He then "gripped the starting lever with both hands and went off with a thud. The laboratory got hazy and went dark. Mrs. Watchett came in, and walked, apparently without seeing me, towards the garden door. I suppose it took her a minute or so to traverse the place, but to me she seemed to shoot across the room like a rocket. I pressed the lever over to its extreme position. The night came like the turning out of a lamp, and in another moment came tomorrow. The laboratory grew faint and hazy, then fainter and ever fainter. Tomorrow night came black, then day again, night again, day again, faster and faster still. . . The dim suggestion of the laboratory seemed presently to fall away from me, and I saw the Sun hopping swiftly across the sky, leaping it every minute, and every minute marking a day. I supposed the laboratory had been destroyed and I had come into the open air. I had a dim impression of scaffolding, but I was already going too fast to be conscious of any moving things. . . Then, in the intermittent darknesses, I saw the Moon spinning swiftly through her quarters from new to full, and had a faint glimpse of the circling stars. Presently, as I went on, still gaining velocity, the

palpitation of day and night merged into one continuous greyness; the sky took on a wonderful deepness of blue, a splendid luminous colour like that of early twilight; the jerking Sun became a streak of fire, a brilliant arch, in space, the Moon a fainter fluctuating band, save now and then a brighter circle flickering in the blue."

"I saw trees growing and changing like puffs of vapour, now brown, now green; they grew, spread, shivered, and passed away. I saw huge buildings rise up faint and fair, and pass like dreams. The whole surface of the Earth seemed changed—melting and flowing under my eyes. . . Presently I noted that the Sun-belt swayed up and down, from solstice to solstice, in a minute or less, and that, consequently, my pace was over a year a minute; and minute by minute the white snow flashed across the world, and vanished, and was followed by the bright, brief green of spring."

Later he "saw great and splendid architecture rising about me, more massive than any buildings of our own time, and yet, as it seemed, built of glimmer and mist. I saw a richer green flow up the hillside and remain there without any wintry intermission. Even through the veil of my confusion the Earth seemed very fair. And so my mind came round to the business of stopping." Stopping was, evidently, a risky business, as it "involved the jamming of myself, molecule by molecule, into whatever lay in my way.". But the risk had to be taken, and he fortunately found himself in an unobstructed space, and was flung headlong into a garden lawn during a hailstorm of A.D. 802,701.

In this future world he finds the surface populated by the eloi, degenerate descendants of the upper classes, graceful, but frail, small, and lacking intelligence and determination. They live on fruits in a garden-world from which all dangerous animals, insects, and harmful bacteria have long been eliminated. The effeminate men can hardly be distinguished from the women, and all live together in huge halls.

Underground live the morlocks, almost equally degenerate descendants of the working classes of the present day who have become accustomed to the darkness of the industrial underworld and have lost the ability to withstand light. They feed upon the eloi, whom they kill during the dark nights.

At the beginning of the Time Traveller's visit to the future the morlocks secrete his machine, leaving him much worried about the prospect of being marooned in the future. He makes friends with the eloi, specially with one called Weena. Eventually he gets into a fight with the morlocks, who capture Weena. The Time Traveller searches for her in vain, and then falls into a trap laid by the morlocks and baited with the time machine. But no trap can hold a machine which travels in time, and the Traveller escapes into the yet more distant future.

"As I drove on, a peculiar change crept over the appearance of things. The palpitating greyness grew darker; then—though I was

still travelling with prodigious velocity—the blinking succession of day and night, which was usually indicative of a slower pace, returned, and grew more and more marked. . . The alternations of night and day grew slower and slower, until they seemed to stretch through centuries. At last a steady twilight brooded over the Earth, a twilight only broken now and then when a comet glared across the darkling sky. The band of light that had indicated the Sun had long since disappeared; for the Sun had ceased to set—it simply rose and fell in the west, and grew ever broader and more red. All trace of the Moon had vanished. The circling of the stars, growing slower and slower, had given place to creeping points of light." Finally the Sun stands still, and the Traveller observes a temporary increase in brilliancy. Then he stopped, finding a black sky and an atmosphere more tenuous than that of the present day. He is attacked by a giant crab and moves on once more, watching the Sun grow larger and duller, until at a period thirty million years from now the Sun obscured nearly a tenth part of the sky. At this time he sees an eclipse of the Sun, which he attributes to the planet Mercury passing very near the Earth. Then he found it too cold for comfort, and returned.

Just before his arrival he sees Mrs. Watchett cross the room once more. "The door at the lower end opened, and she glided quietly up the laboratory, back foremost, and disappeared behind the door by which she had previously entered." He arrives at almost eight o'clock in the evening of the same day he left, asks his friends to wait dinner for him, eats, tells his story, and fails to convince. Later he goes on another trip, from which he never returns.

(For *Errors* see p. 438.)

A Rose Colored Image of the Sun

By C. C. WYLIE

Several years ago, when projecting an image of the Sun on a piece of white cardboard with a 5¼-inch refracting telescope, the writer and a group of students viewing the sunspots were surprised to see the entire image of the Sun turn to a distinct rose color. It is a common experience when viewing sunspots in this way to see thin clouds move over the Sun's disc, these showing dark against the lighter image of the Sun. In this case, however, there was very little darkening, but instead the rose color covered uniformly the entire disc of the Sun.

When the rose color appeared, we stepped outside of the observatory, but nothing could be seen in the sky which conceivably could account for this change of color. No smoke, dust, or haze was visible, excepting near the horizon and at a considerable distance from the Sun. On the whole, the sky appeared quite clear.

After the occurrence of this phenomenon, we inquired of some

physicists and meteorologists, including Professor W. J. Humphreys of the U.S. Weather Bureau, giving the circumstances in more detail than in the preceding paragraph. No one was able to offer a suggestion on what might have passed over the Sun to remain almost invisible, yet produce the rose color by absorption and scattering.

The Iowa student's observatory was located about three blocks west of the Iowa River from 1924 to 1943, and it was there at the time the rose color was noticed. This year, it was moved to the roof of the Physics Building, about two blocks east of the Iowa River. No repetition of the rosy tinge was observed at the west side location, but on the afternoon of July 9, 1943, the rose color appeared on an image projected with an 11-inch portable reflector set up on the roof of the Physics Building.

On this second occasion there were numerous scattered clouds of the towering cumulus type, two of these clouds showing signs of the ice crystal formation, and approaching the cumulonimbus phase. In the vicinity of the Sun, however, nothing could be seen appreciably different from many other days on which the Sun had been observed through scattered, or broken, clouds without showing the rose color.

There was a light wind from the east on this occasion, and there are sources of smoke, including a laundry and two hotels a few blocks east and south of the Physics Building. These facts, with the knowledge that the Sun's disc appears reddish when seen through smoke, suggested that partially dissipated smoke might have been responsible for the rosy color of the projected image of the Sun.

To test this hypothesis, binoculars were taken to a point where a heavy cloud of smoke passed over the face of the Sun, on a day when there was only a light wind. By moving out away from the source of smoke, but keeping the line of dissipating smoke moving over, or toward, the Sun, it was found that a large cloud of nearly transparent dissipating smoke does give a rosy tinge to an image of the Sun. This is distinctly different from dust or haze. Through dust, the Sun's image appears colorless or yellowish, and through haze, the Sun's image may even appear bluish.

Our guess is that the rosy tinge observed several years ago, when the observatory was west of the Iowa River, was due to dissipated smoke from the University power house, three to four blocks east of the old location of the observatory. On that particular occasion, a light wind may have brought a large cloud of smoke, too transparent to attract attention, directly between the observatory and the Sun.

On the afternoon of July 9, 1943, a large, nearly transparent, cloud of smoke from the previously mentioned laundry may have drifted between the Physics Building and the Sun, and produced the rosy tinge on the projected image of the Sun.

University of Iowa, August 23, 1943.

Aurora Borealis of August 30-31, 1943

By N. T. BOBROVNIKOFF

Aurorae are not often seen in our latitude at any time, and, consequently, a brilliant aurora almost at the epoch of sun-spot minimum seems to call for a special notice.

The aurora was first noticed August 31, 2^h U.T., when it began in the form of a low arch in the north. Between that time and 5^h U.T., luminous streaks resembling cirrus clouds appeared and disappeared, generally extending from NW to SE and extending past the zenith. At 5^h U.T., a double arch was formed in the north. No well-defined curtains could be seen, but the whole northern sky from altitude 70° to the horizon was full of diffuse masses of luminous matter slowly pulsating. Once in awhile a very rapid transference of luminosity occurred, always from the horizon upwards in several quick pulses. I cannot remember having seen this phenomenon before and I can compare it only with sheet lightning.

The height of activity was reached at $5^h\ 30^m$ U.T., with very brilliant green streamers in the north which seemed to be moving from west to east. Soon after this the whole display subsided although the northern sky was bright until dawn.

Slight aurora was suspected on several nights previous to August 30 and also on the night of August 31-September 1.

PERKINS OBSERVATORY, DELAWARE, OHIO.

Marvelous Voyages—VIII

ERRORS IN WELLS' THE TIME MACHINE

By LAURENCE J. LAFLEUR

1. There are serious objections to considering time as an extra dimension of space, but these are too complex for consideration in detail. For these objections, consult "Time as a Fourth Dimension" in the *Journal of Philosophy,* March 28, 1940.

2. Reverse direction in time travelling involves contradictions. If we could go back into the past, for example, we could kill our ancestors in infancy so that we could never have been born.

3. Forward travel is possible: it is equivalent to a sort of cold storage wherein a person, going to sleep in the present, would wake up in the future. But his body would be continuously visible in the interval.

4. The whole idea of travel in time implies the notion of several "times." In the present instance, the Time Traveller goes thirty million years into the future and back, spending eight days of his psychological time and having ten hours disappear from his life in our own present.

5. If the machine travels in time, what is carried with it? If the man seated in the saddle, why not the floor, the air, the room? It would seem more plausible if there were an enclosed chamber and only what was inside were moved in time.

6. The threshold works in both ways. If A moves so fast that B cannot see A, neither can A see B. But the Traveller sees Mrs. Watchett and Mrs. Watchett does not see the Traveller.

7. There should be an enormous "Doppler effect." If we travelled a year a minute, the waves emitted by the Sun in the course of a year would enter the eye in the course of a minute. Evidently the first phenomenon of time travelling would be a shift of light to the violet end of the spectrum. The Sun would get bluer and bluer, and probably disappear altogether in a short time. In the meantime hot objects would become luminous. Just what the world would look like when we were travelling at high "speed," is difficult to say, but it would certainly not look as it ordinarily does.

8. Why should the machine follow the surface of the Earth in its rotation and revolution and in its other motions? And if it does the Traveller is being whirled once around the Sun and 365 times around the Earth in, say, a minute. Would he not feel the effects?

9. As long as the Traveller could see moving objects, such as the Sun, Moon, and stars, why should fixed objects appear hazy?

10. The Moon could not be seen spinning through her quarters. Her movements would make it difficult to follow her, and the Sun would dazzle the eyes too much to let the Moon be easily seen.

11. The Moon could not be seen as a second band, since it would be utterly obliterated by sunlight.

12. Still more would the stars be invisible.

13. Even if lucky enough not to find his body occupying the space already occupied by another solid object, there would certainly be air. This air would give a severe case of the "bends"; in fact would almost certainly knock out the heart and cause other fatal injuries.

14. Division into two species can occur only if intermarriage between two groups is almost completely eliminated. There was nothing in the world of 1907, nothing now, to suggest that this might happen.

15. There would be no lack of light in the underworld. We must expect artificial illumination, and possibly from that the loss of ability to compensate and see in the dark, but not *vice versa.*

16. If the Time Traveller wished to see Weena again, he need only have returned to the time before she was taken by the morlocks.

17. Those visible comets are even more absurd than the visible stars already mentioned.

18. There is no reason to suppose that the Earth will approach the

Sun in the future: it is more reasonable to assume that we will be farther away.

19. If the sky of the future were black, the implication would be not that the atmosphere was slightly more tenuous, but that there was hardly any atmosphere left, in which case the Time Traveller would die.

20. Thirty million years is an absurdly small time to allow for these astronomical changes to occur. The Earth has been in its present situation, or approximately so, for a thousand times that period already, to our present knowledge.

21. If the size of the Sun has not changed, the Earth would have to be only two million miles from the Sun to produce the apparent size mentioned. Presumably the same phenomenon would occur with other planets. If any interior planet still existed, it would almost certainly be Venus rather than Mercury.

22. Why should the Time Traveller ask his guests to wait? He could just as easily go back one or two hours more and give himself the extra time.

The Planets in November, 1943

By ALICE H. FARNSWORTH

NOTE: Greenwich Civil Time is used unless otherwise stated. To obtain Eastern Standard Time subtract 5 hours; Central Standard Time, 6 hours, etc. War Time in each zone is one hour later than Standard. Phenomena are described as seen from latitude 45° N. *The American Ephemeris and Nautical Almanac* is the source of the data.

Sun. The Sun starts the month in the constellation Virgo (α 14^h 21^{m}3, δ — 14° 4′7), passes through Libra, and ends it in Scorpio (α 16^h 24^{m}6, δ — 21° 38′0 on December 1).

This is the time of year when the real Sun gets farthest ahead of the fictitious or mean Sun on which our time-reckoning hangs. The difference is 16^m 22^s on November 4. However, because of War Time you will find the sun-dial *slow* of your watch on that date by an amount equal to 60^m — 16^m ± your distance from your standard meridian. Use upper sign if you are west of the meridian.

Moon. Dates of phenomena are as follows:

		h	m
First Quarter	November	5	3 22
Full Moon		12	1 26
Last Quarter		19	22 43
New Moon		27	15 23
Runs low	November	2	21
In perigee		6	10
Runs high		16	1
In apogee		19	10
Runs low		30	5

This Full Moon offers excellent views of the western and northern limbs simultaneously. One should see well the western maria and objects beyond ray-girt Anaxagoras in the north.

Mercury is too near the Sun to be observed, passing superior conjunction on the 10th.

Venus is a brilliant "morning star," reaching greatest elongation west on November 16. On the morning of November 23 the planet and waning crescent Moon (3° north) will be in a straight line with Denebola (above) and Spica.

Mars and *Saturn* both spend the month moving westward in Taurus. Mars, ruddy and brighter than the other, is 5° west of it on the 1st and more than doubles this separation by the 30th. The proximity of the bright stars in Taurus (see chart in January issue) makes the detection of the motions of both planets very easy. The waning Moon passes by, slightly to the south, the week-end of November 12-14.

Mars is actually nearest the Earth, about 50 million miles away, on the 28th, but its slowly-changing apparent diameter in the telescope does not vary by 5 per cent for fully two weeks before and after this date.

Jupiter is moving very slowly eastward in Leo, a few degrees west of Regulus. On November 19 it reaches west quadrature and on the same day is occulted by the last-quarter apogee Moon (visible in Asia). This is the fourth in a series of nine occultations taking place (August, 1943, to May, 1944) while the planet is in the vicinity of the ascending node of the Moon's orbit.

Uranus comes to opposition on the 29th. It contributes to the planetary traffic in Taurus and should be easy to follow with an opera-glass, moving westward just south of υ and κ Tauri (see chart in January issue).

Neptune is west of the Sun in Virgo, and is passed by Venus on the 13th.

In a previous article (in the March issue) the *method of observing* an occultation was discussed in some detail. The *computation* of the quantities useful to the lunar analyst, and a brief account of what he does with them is our present subject. In its treatment the writer gratefully acknowledges valuable criticisms by Dr. Dirk Brouwer.

At the instant of occultation the Moon's radius (σ) drawn to the point at its edge where the star disappears must evidently equal the angular distance (σ') between the star and the Moon's center. If the computed values of these two quantities do not agree, the blame is thrown on the predicted place of the Moon's center, since the other elements involved (the Moon's radius and the position of the star on the celestial sphere) are known with considerable accuracy. The purpose of the reduction is, then, to find the value of the residual ($\sigma' - \sigma$), which leads to the error in the Moon's orbital longitude as given in existing tables. Assumed as available to the computer are T, the G.C.T. of the occultation; λ, the observer's longitude; and certain functions of his latitude and local terrestrial radius.

The fundamental principles of the method of reduction are most easily understood if one takes a "star-view" of the situation. A star with given right ascension and declination (α', δ') would in general see any point H on the Earth describing part of an ellipse during the hours when it was on the hither side of the planet. Conceivably the Moon in its monthly circulation of the Earth may pass over H, obscuring it from the star's view. The Moon's edge would overtake H and cover it at the same instant that the observer at H watching the star would see it occulted at the eastern limb of the Moon (the instantaneous coordinates of its center being α and δ).

Refer now to Figure 1 which represents a section of the Earth cut through its center C, perpendicular to the line joining the star to C. The section is a portion of the so-called fundamental plane. The point C is used as a center of coordinates which are expressed in seconds of arc. M is the center of the

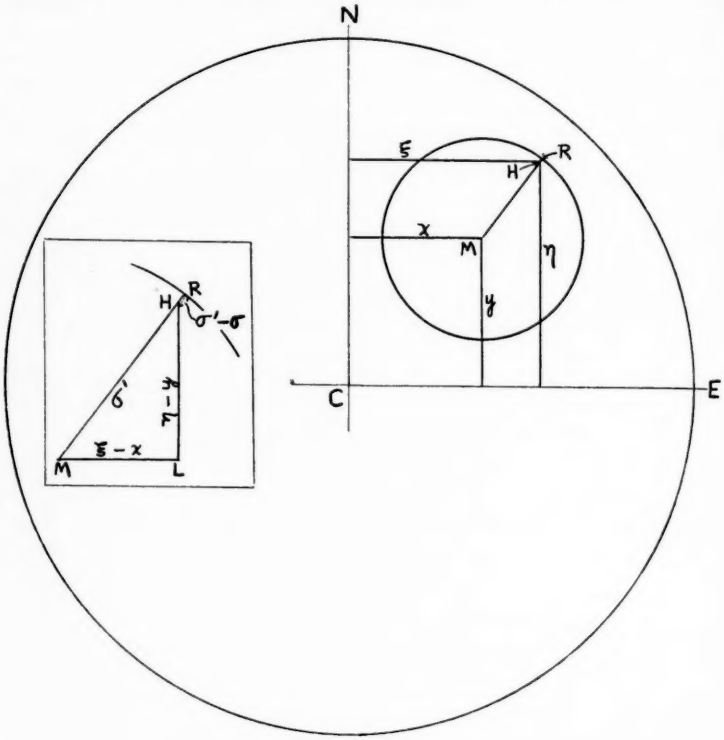

FIGURE 1

Fundamental plane as seen from star when Moon's edge passes over H. At left, inset (enlarged) shows negative residual $\sigma' - \sigma$, since MR is greater than MH.

projected Moon (or of its sensibly cylindrical shadow directly behind it, in the star-view), according to the lunar tables, at the time T. H may be supposed to be South Hadley,[1] and R the end of the lunar radius directed toward it. σ is thus MR and σ' becomes in the reduction the distance from M to the disappearing H.

The Moon's radius is known to be slightly more than a quarter that of the Earth (the ratio k adopted[2] for occultation work being 0.2724953, corresponding

[1] Figures 1, 3, and 5 represent approximately the occultation of 19 Piscium for which circumstances are noted later in this paper.

[2] *Astronomical Journal*, **46**, p. 61, 1937.

to a lunar semi-diameter of 932″.63), the latter being expressed as the number of seconds of arc in the horizontal parallax of the Moon, corrected for the difference between arc and chord. The desired quantity is thus very nearly:

$$\sigma = 0.2725\ (\pi'' - 0''.16)$$

where π'' is carefully interpolated for the instant T from half-daily values given in *The American Ephemeris.*

The angular distance σ', MH in the fundamental plane, may be regarded as the hypotenuse of a right triangle whose sides are the respective differences in rectangular coordinates of M and H. To find it, proceed as follows:

1. The Moon's coordinates, x and y, from C as origin are indicated in Figure 1. Note that M will appear about as far north or south from C as there is difference between δ and δ', and east or west from C by a distance determined by $(\alpha - \alpha')$; *i.e.,*

$$x = 15\ (\alpha - \alpha')^s \cos \delta$$

where the factor $15 \cos \delta$ is needed to change from seconds of time to seconds of arc, and

$$y = \delta - \delta'$$

approximately.

2. The coordinates of H are designated ξ and η and must be derived from known values of ρ' (radial distance of H from Earth's center, including elevation) and ϕ' (its geocentric latitude). The latter quantities locate the place on the surface of the Earth and must be projected back into the fundamental plane. In Figure 2, QCF being the plane of the Earth's equator,

$$CT = \rho' \cos \phi' \text{ and } CV = \xi = CT \sin (\theta - \alpha').$$

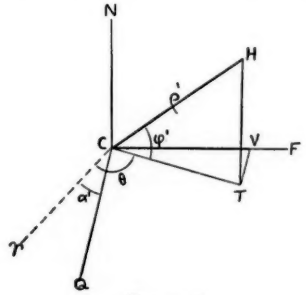

FIGURE 2

Plane NCQ contains star, east of Vernal Equinox by an amount α'. H, east of equinox by θ (sidereal time of occultation) lies in plane NCT. TV is parallel to QC.

The quantity ρ' as given in *The American Ephemeris* must be multiplied by π'' to convert it into angular units. Thus we have:

$$\xi = X'' \sin (\theta - \alpha') \text{ where } X'' = \pi'' \rho' \cos \phi'.$$

The expression for the north-south coordinate of H, designated η, is similarly derived but somewhat more complicated because the plane QCF does not in

general pass through the star, so that the axes must be rotated. Its value is:

$$\eta = Y'' \cos \delta' - X'' \sin \delta' \cos (\theta - \alpha') \text{ where } Y'' = \pi'' \rho' \sin \phi'.$$

3. The required distance[3] σ' now follows from

$$\sigma' = \sqrt{(\xi - x)^2 + (\eta - y)^2}.$$

The residual quantity $\Delta\sigma$ $(= \sigma' - \sigma)$ is related to the errors in the orbital longitude (ΔL) and latitude (ΔB) of the tabular Moon by the observation equation

$$\Delta L \cos (\rho - \chi) + \Delta B \sin (\rho - \chi) = \sigma' - \sigma$$

where ρ and χ are angles shown in Figure 3. Angle NMH, designated χ, is the position angle of the Moon's radius MR and is determined from $\tan \chi = (\xi - x)/(\eta - y)$. Angle NMD, called ρ, is the position angle of the Moon's orbital motion and follows from $\tan \rho = 15\, \Delta\alpha^s \cos \delta / \Delta\delta$ where $\Delta\alpha$ and $\Delta\delta$, the variations in the Moon's α and δ at T, must be found from *The American Ephemeris* data.

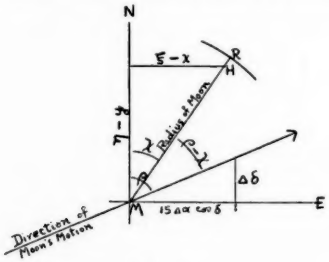

FIGURE 3
Relation of angles to Moon's radius and direction of motion.

When σ' (= MH in Fig. 3) computed for the time of the observation with the aid of the Moon's ephemeris position, is less than the Moon's semi-diameter σ, a negative residual RH (greatly exaggerated in Fig. 3) is obtained. The determination of the error in the Moon's position by means of such a residual is a problem[4] rather similar to that of the line of position in navigation. Throwing the full blame upon the calculated place of the Moon's center, the interpretation of the observation is that actually, at the time of the observation, the Moon's center (M in Fig. 4) must have been at a distance σ from H, *i.e.*, on a circular arc with H as center and σ as radius. The Moon's position is so well represented by the modern tables that the error is always small compared with the Moon's radius. Consequently it is permissible to replace the circular arc by the tangent to the circle perpendicular to MH. One single observation of an occultation furnishes the information that the Moon's center must lie somewhere on this tangent; for example at M', chosen at random.

The validity of the observation equation given above is evident from Figure 4

[3] In order to change the subtraction in $\xi - x$, $\eta - y$ to an addition, Innes changed the sign in the definition of x and y. On this account, on computation sheets based upon Innes' formulae, x and y should everywhere be changed to $-x$, $-y$ to conform to the notation in this article which follows the notation used by Chauvenet, Comrie, and others.

[4] Treatment here and Figure 4 due to Dr. Brouwer.

where each angle marked with an arc is equal to $\rho - \chi$; ΔL and ΔB are shown by heavy lines, and their projections parallel to MH by dash lines. Independent of the particular choice of M, the equation is satisfied.

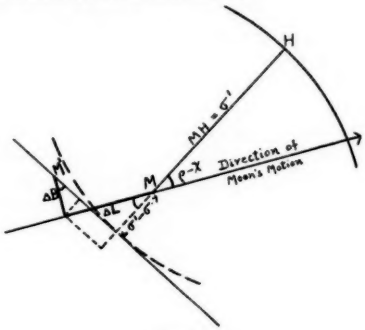

FIGURE 4
Relation of residual $\sigma' - \sigma$ to error in Moon's position, for case of negative residual, MH less than σ.

Accordingly the angles χ, ρ and their difference and the quantities $p [= \cos(\rho - \chi)]$ and $q [= \sin(\rho - \chi)]$ are included in the reduction. With $\Delta\alpha$ and $\Delta\delta$ are tabulated two coefficients, $15 \cos \delta' \sin \chi$ and $\cos \chi$, essential to computing a differential correction to $\Delta\sigma$ if at a later date alterations in the adopted position of the star become necessary.

It is customary to add to the tabular α and δ of the Moon certain amounts ($k\Delta\alpha$, $k\Delta\delta$), dependent on a value of k (not to be confused with the ratio k mentioned earlier) determined and announced in advance by Dr. Brouwer. These corrections are equivalent to adding a number of seconds of arc to the mean longitude of the Moon. "They reduce the difference between the observed and computed places (apart from observational errors) to less than a second of arc, and thus to a small extent reduce the work of reduction. The saving of time in the later discussion is very considerable."[5] The correction has been gradually diminishing and since December 28, 1940, the designated value of k is zero.

Noteworthy also is the fact that the most tedious and tricky part of the entire reduction just described comes near the beginning, in the interpolation (involving second differences) for the instant T, of the lunar quantities α, δ, $\Delta\alpha$, $\Delta\delta$, and π.

To recapitulate: the reduction of an occultation consists in deducing from certain raw materials (namely, the exact time of the occultation, the observer's position on the Earth, the apparent position of the star at the moment, the instantaneous position of the Moon's center and its horizontal parallax as given in the tables) a residual quantity which represents mainly the difference between the Moon's tabular and true longitude. A printed form, designed for working the problem by logarithms, according to the formulae of Innes as given above, involves 67 items logically arranged on an 11 × 12-inch sheet. *The American Ephemeris* and a 5-place table of logarithms are required, a table of squares

[5] *Popular Astronomy*, **35**, p. 17, 1927.

is useful, and in this form of the work a computing machine is desirable only for making the necessary interpolations from *The American Ephemeris.*

Homogeneity of results is sought by confining reduction to stars contained in the "Catalogue of 3539 Zodiacal Stars for the Equinox 1950.0" by James Robertson (Vol. X, Pt. II of the *Astronomical Papers of The American Ephemeris*). The star places used may thus be supposed to belong to a consistent system.

As recently as 1937, L. J. Comrie, then Superintendent of the British Nautical Almanac Office, cast the problem of reducing occultations into simpler form by concentrating into published "Reduction Elements" all quantities for a given occultation not dependent on the observer's position. The computer's labor is reduced to filling in 38 items on a 4 x 6-inch card, of which 8 are furnished to begin with and 10 represent the final results. The form is arranged for handling with a computing machine rather than by logarithms. Local tables computed for the latitude of the observer facilitate greatly the computing of the observer's coordinates, and four other tables printed in the *Nautical Almanac* lighten the labor at several points.

In this shorter form of reduction, the unit is changed to the radius of the Moon, the position of the star (α', δ') nowhere appears as such, and the local hour angle (h) of the occultation is established through μ_o (see below). The reduction elements, with definition, are as follows:

μ_o = the G.H.A. of the star at 0^h on the day of conjunction

$r = \cos\delta'/k$ $\quad s = -\sin\delta'$ $\quad v = 150\cos\delta'$

$\pi_y = \sin 1''/k \sin\pi$ $\quad F = -1000\cos\rho$ $\quad G = 1000\sin\rho$

x, y = coordinates of Moon's center for integral hours of Gr. time from which they may be interpolated for T.

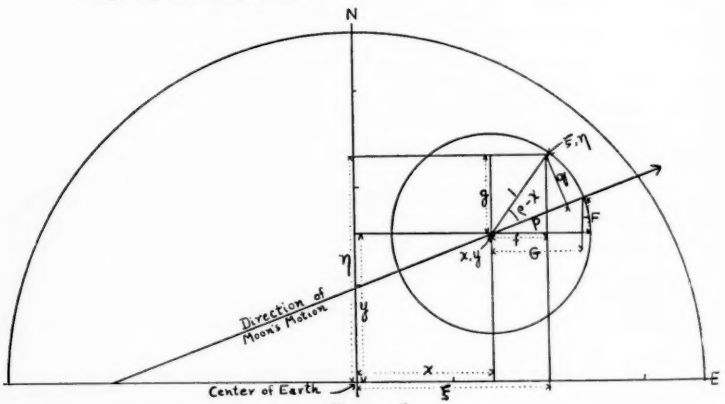

FIGURE 5

Occultation diagram, with labels as in Comrie reduction for 19 Psc as seen from South Hadley, Mass., on 1938 January 8. (NOTE: f and g in the figure should be —f and —g, respectively.)

The observer's place is conveniently introduced through a table made for the local value of A ($= \rho\cos\phi'/k$) whence may be read ξ ($= A\sin h$) and Q ($= A\cos h$), tabulated with h as argument. Then

$$\eta = \rho\sin\phi' \cdot r + Q \cdot s$$

$\Delta\sigma$ is taken from a table entered with arguments π_y and $f^2 + g^2$

where $f = x - \xi$ and $g = y - \eta$

p, q (defined earlier) are read from a critical table with argument $Ff + Gg\ (= -1000\,q)$

Coefficients of $\Delta\alpha$ and $\Delta\delta$ are $-0.1vf$ and $-g$, respectively.

Several parallel or analogous items in the two forms of reduction are shown herewith for the star 19 Piscium, occulted at South Hadley, Massachusetts, at T = 1938 January 8, $0^h\,37^m\,18^s.7$. Accompanying each item is its corresponding serial number and designation on the form in question. A conventional difference in the signs of x and y will be noted. In cases marked * the ratio Innes to Comrie is $k\pi''$ (= 928".4). At **, the factor is $(k\pi'')^2$; at † one item is the reciprocal of the other. Figure 5, given as a further aid in indicating the relationship between the two methods, is drawn for the same occultation and is self-explanatory. The writer is indebted to R. D. Cooke, an experienced observer and computer of occultations, for submitting a diagram similar to this.

	Innes			Comrie	
26	$\theta - \alpha'$	$3^h\,11^m\,24^s.80$	10	h	$3^h\,11^m.415$
21	π''	3407".2	26	π_y	.00108
30	x	—1328.9	17	x	+ 1.4316 *
51	y	—1433.3	22	y	+ 1.5437 *
33	ξ	+1872.7	18	ξ	+ 2.0170 *
41	η	+2182.8	21	η	+ 2.3511 *
52	$x + \xi$	+ 543.8	19	f	— 0.5854 *
53	$y + \eta$	+ 749.5	23	g	— 0.8074 *
54	χ	35°58′	24	G	931
60	ρ	68 31	20	F	—366
61	$\rho - \chi$	+ 32 33	31, 2	p, q	+ .84, +.54
64	σ'^2	857469	25	$f^2 + g^2$	0.9946**
65	σ'	926".0	..	...	....
66	$\sigma = k\pi''$	928.4	26	π_y	.00108†
67	$\Delta\sigma$	— 2.4	36	$\Delta\sigma$	— 2".5

Through the year 1941, reduction elements for each star in the list of those that can be seen occulted from somewhere on the Earth during the year were published yearly in the *Nautical Almanac*. The next year, "Occultation Reduction Elements for the Year 1942," computed by the British Nautical Almanac Office, were published as a separate pamphlet in the U.S.A. by the American Section of the International Astronomical Union. Beginning with 1943, reduction elements are no longer to be furnished for all stars, but apparent places of all stars occulted have been added to the data in the *Nautical Almanac*. A modified scheme is announced in its 1943 issue (page 597) from which the following is quoted:

"The general principle of the modified scheme is similar in concept to that underlying the reduction elements, but differs fundamentally in that the centralization of the major portion of the reduction (with the exception of the computation of the apparent places of occulted stars) is done *after* observation instead of *before*; this obviates the large wastage, inherent in any large scale program of prediction, which was the only disadvantage of the reduction elements. By the precomputation of the apparent places of the occulted stars, the observer is able to complete, with little work, half the reduction card; he can in fact combine the position of the star, the place of observation and the time of observation into

data which can be immediately combined in their turn with the position of the Moon to give the complete reduction. The basis of the method now adopted is thus to centralize, after observation, all that portion of the reduction dependent on the position of the Moon; it is this portion of the work that requires the use of calculating machines, which may not be immediately available to all observers, and which can be greatly simplified by the use of unpublished tabulations for the Moon at a small intervals of time. In the details that follow, it will be noted that three of the four printed tables are still used, that the special tables for each observing station will still be required and that the printed cards will still be the medium for the recording of the reductions. This scheme does not compel observers to take advantage of the system of centralised reduction; other methods of reduction are still available and observers who prefer to reduce their own observations will now have the apparent places of all occulted stars brighter than magnitude 7.5."

Further details are given on pp. 598-9 for those who wish to follow this plan.

The uncertainty attendant on sending mail across the ocean in war-time and the fact that many observers find satisfaction in reducing their own observations compel careful consideration as to the best future plan of procedure in the U.S.A. For the present it appears that we shall return to the Innes form of reduction, for most observations. Only where a single occultation has been observed several times is it probable that the precomputation of reduction elements will be any time-saver. Observations should be sent in at least twice a year (January 1 and June 1) and computers will be expected to go back to the earlier form of reduction.

For greater detail about the Innes formulae, see the original article by Innes in *Astronomical Journal,* **35**, 155, 1924, or the discussion, liberally illustrated by diagrams, by Leland S. Barnes in POPULAR ASTRONOMY for March, 1929, p. 120. Slight changes in the reduction forms have been made since the latter article appeared. The "Comrie method" appears in *Astronomical Journal,* **46**, 61, 1937, and is completely dealt with in "The Prediction and Reduction of Occultations," a Supplement to the *Nautical Almanac* for 1938. The writer is indebted to all these publications. Attention is called to the fact that a graphical method for the approximate *prediction* of occultations is outlined by Mr. Fitzpatrick in *Sky and Telescope* for June, 1943. This subject has not been touched upon here. It is important for would-be observers more than two or three hundred miles from the standard stations.

The very important question remains: "What light have the thousands of occultations reduced in the last twenty years or so shed on the problem of the Moon's motion?" In 1922, Professor E. W. Brown wrote:[6]

> "The memoirs of Dr. J. K. Fotheringham on the ancient eclipses and those of C. I. Taylor and H. Jeffreys on tidal friction in shallow seas have largely cleared away the doubts that surrounded the old hypothesis that the Moon's apparent residual acceleration is, in reality, due to a retardation of the Earth's rate of rotation."

Four years later he published a special request[5] for more observations of occultations on the ground that

> ". . . observations of occultations of stars by the Moon can furnish valuable data concerning the apparent deviations of the Moon from its

[6] *Astronomical Journal,* **34**, p. 52, 1922.

gravitational orbit. Their comparative freedom from systematic errors renders them of particular use in the discussion of long period changes, and the 'accidental errors,' mainly those due to the roughness of the Moon's edge, can be eliminated with a sufficiently large number of observations."

Annually since that time a compilation and discussion of occultations observed during one year has been published from Yale Observatory in the *Astronomical Journal*. For 1926, 160 observations were discussed; for 1934, 1483. Beginning with 1936 when Dr. Brouwer resolved[7] to include only stars whose places belonged to one homogeneous system, the number dropped below a thousand.

Each reduced occultation furnishes an observation equation of the form $p(\Delta L - \Delta L_o) + q\Delta B = \Delta\sigma$ where ΔL and ΔB are the unknowns, and ΔL_o is the preliminary correction to the Moon's longitude. Normal equations are formed for the 12 or 13 lunations of the year and the solution found by lunation and by quarter. A steady decrease in ΔL, "the adopted mean value of the apparent difference of the mean longitude of the Moon from its tabular value for the year," is noted from approximately 7″ in 1927 to 1″ in 1940. Deviations of the Moon's mean longitude from the tables, when plotted against time within the year show an annual tendency to be positive in the early part of the year and negative in the latter part. In 1930 Brouwer was inclined to attribute this annual term largely to systematic errors in star places.[8]

In recent years, when the results based upon more homogeneous star positions had become available, it was found that the amplitude of the annual term varies systematically, and passed through a minimum about 1936. This indicates that the full explanation is more complicated.

Brown[9] noticed a similar fluctuation in the residuals in the Moon's latitude, but with a period of fourteen months. This was explained by Watts[10] as due, in part at least, to the irregularities in the Moon's limb.

[7] *Astronomical Journal*, **47**, p. 191, 1939.
[8] *Astronomical Journal*, **40**, p. 161, 1930.
[9] *Monthly Notices R.A.S.*, **93**, p. 603, 1933.
[10] *Astronomical Journal*, **48**, p. 170, 1940.

Occultation Predictions for November, 1943

(Taken from the *American Ephemeris*)

Date 1943	Star	Mag.	Immersion: Greenwich C.T.	Immersion: *a*	Immersion: *b*	Immersion: Angle E from N	Emersion: Greenwich C.T.	Emersion: *a*	Emersion: *b*	Emersion: Angle E from N
			h m	m	m	°	h m	m	m	°
Occultations Visible in Longitude +72° 30′, Latitude +42° 30′										
Nov. 3	33 Sgr	5.8	0 58.4	..	..	159	1 12.8	..	..	185
5	19 Cap	5.9	1 29.0	—0.8	0.0	52	2 33.0	—0.9	—1.3	270
7	70 Aqr	6.2	1 43.1	..	..	2	2 18.7	..	..	305
13	63 Tau	5.7	9 21.4	—1.2	+0.4	47	10 17.7	—0.4	—2.4	296
15	64 Ori	5.2	3 56.7	—1.3	+1.1	96	5 10.8	—1.3	+1.9	242
15	68 Ori	5.7	9 37.1	—1.3	—2.4	125	10 43.1	—1.5	0.0	238
17	209 B.Gem	6.1	5 50.4	—1.4	+1.3	90	7 13.6	—1.8	+0.6	274
22	*b* Vir	5.2	11 36.3	—2.1	+0.2	100	12 57.1	—1.4	—1.8	320

	Occultations Visible in Longitude +91° 0′, Latitude +40° 0′											
Nov. 3	33	Sgr	5.8	0	26.0	—2.0	—2.2	131	1	14.6	—0.5	+0.7	214
5	19	Cap	5.9	1	9.3	—1.1	+1.0	34	2	10.7	—2.0	—1.6	289
13	179	B.Tau	6.0	0	3.1	..	..	152	0	12.8	..	..	174
13	63	Tau	5.7	8	53.1	—1.7	+0.5	60	10	7.4	—1.3	—1.5	277
15	64	Ori	5.2	3	38.9	—0.4	+1.6	82	4	46.0	—0.8	+1.6	254
15	68	Ori	5.7	9	13.2	..	..	145	10	2.8	..	..	211
17	209	B.Gem	6.1	5	30.4	—0.5	+1.6	82	6	42.2	—1.1	+1.0	276
22	*b*	Vir	5.2	11	6.7	—1.3	—0.3	127	12	28.2	—1.8	0.0	288
24	80	Vir	5.8	12	3.8	—0.4	—1.7	161	12	58.2	—1.9	+1.8	255
	Occultations Visible in Longitude +120° 0′, Latitude +36° 0′											
Nov. 3	ξ	Sgr	3.6	1	36.7	—1.8	—0.3	79	2	55.0	—1.5	—0.9	267
5	19	Cap	5.9	0	20.8	..	..	15	0	59.5	..	..	320
5	21	Cap	6.5	3	58.3	—0.8	+1.2	31	4	55.9	—1.9	—1.8	289
13	63	Tau	5.7	7	53.8	—1.7	+2.1	51	9	16.1	—2.4	—0.2	270
15	64	Ori	5.2	3	35.6	+0.5	+1.5	63	4	28.4	—0.1	+0.9	276
15	68	Ori	5.7	8	5.6	..	..	138	8	51.5	..	..	202
17	209	B.Gem	6.1	5	25.0	+0.5	+1.7	65	6	18.2	—0.3	+0.5	292
17	10	H.Cnc	6.1	13	35.7	—1.3	—3.4	146	14	42.6	—2.5	+0.4	244
18	*X*	Cnc	6.7	13	31.9	—2.7	+0.4	80	14	51.2	—1.3	—3.0	320
18	B.D.+17°1979		6.3	14	59.7	—2.8	+0.9	60	15	52.9	—0.2	—4.1	342
21	308	B.Leo	5.9	10	35.6	—0.7	+2.3	72	11	32.8	—1.0	—1.4	328
22	*b*	Vir	5.2	10	48.4	—0.4	—1.5	156	11	37.2	—0.9	+2.4	247
30	115	B.Sgr	5.8	0	42.7	—1.5	—1.2	102	1	49.5	—0.7	—0.5	246
30	121	B.Sgr	5.9	1	34.2	+0.1	+1.7	23	2	7.4	—1.9	—3.6	324

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

The number of fireballs in our lists for which reductions are possible grows steadily smaller and nearly all the cases where good solutions may be expected have already been published. It is our aim, however, to put on record such data as may be obtained from poor or partial solutions, so that they may be available for statistical studies by others, always being quite frank as to the probable accuracy of these results. Three rather unsatisfactory cases, such as those mentioned, are given below.

The Perseid shower last month was somewhat above the average in hourly numbers, that is for persons in favorable localities and with good skies, and many brilliant meteors were reported. The press of the country gave even better publicity than usual, so observers were widely scattered, though not as numerous as in some years. This last fact was due to (1) the war and consequent absence of many in military service or industrial work, (2) to cloudy weather which

ruined the plans of many along the eastern seaboard from Maine to North Carolina, at least, though in some localities, as for instance here, we had partially clear weather just at maximum. As reports are still coming in, the résumé of this year's observations will be held for later Notes. The cordial cooperation of so many newspapers and the work of scores of new observers are gratefully acknowledged. The latter will be tabulated by name, along with their individual results.

These Notes will appear shortly before the epoch for the Orionids. This important stream can be detected as early as October 16 and may last until the end of the month. Forty years ago the maximum was on October 19/20, but in recent years the rates on the next three nights have been about equally as good. The Moon on October 20 is at last quarter and very near the radiant. This is rather unfavorable. But by October 22/23 it will have decreased considerably in brightness and also be far enough away to interfere little. It is therefore hoped that our regular observers will make real efforts to get in good sets of observations for several nights on these meteors, connected as they are with the best-known of all comets, Halley's.

On 1934 June 6 at about $11^h 8^m \pm 10^m$ P.M., C.S.T., a great bolide appeared over Kentucky and moving along a southeastern path ended near the Virginia border. Our regional director in Tennessee then was Sterling Bunch, who cooperated so often and so efficiently in both gathering data and aiding in the solution of fireball paths. (For some years past his work with the U.S. Weather Bureau has been of such an exacting and important nature that he has had to give up his very active work with the A.M.S., though continuing a member.) He collected and digested such data as were obtainable, all of which in due time arrived here. The case was superficially examined and laid aside as being probably unsolvable. This summer, however, with others it was turned over to Miss Reilly. Her first plot, plus a further study of the records by me, showed the main trouble. The only plot by a trained observer, Thorpe of Louisville, Kentucky, was of a fine meteor brighter than Venus seen by him (and others there) at $10 \pm$ P.M., while all the others reported the bolide at from 11 to 11:15 P.M. Further, the projections of his azimuths *wholly* miss all the projections from the other stations, falling to the west of them. This precludes an error of one hour in recording the time being the trouble. So regretfully omitting what had seemed our best observation, an approximate solution was made.

I now quote in part Bunch's résumé: ". . . a brilliant meteor . . . From Knoxville, Tennessee, (S2) it was reported as being from one-half to as large as the Moon and bluish-white. . . One Knoxville report stated that it left a glow in the sky for 3 minutes after the meteor disappeared. . . One from Oneida, Tennessee, (S3) . . . 'brighter than the brightest of stars, planets or Moon.' At Bristol, Tennessee, (S4) . . . half as large as Moon. Near Norton, Virginia, (S5) it was decribed . . . as large as a 'passenger train,' and from Norton, Appalacha, and Dunbar, all in S.W. Virginia, it was reported to have exploded with a loud noise with a jarring of window panes. Two considerations would make it appear that this meteor actually reached the Earth. First the jarring noise from the . . . Virginia towns, and, second, all observers say that it disappeared behind mountains or other obstructions, indicating that its end point was very low. A preliminary consideration of the meager reports at hand would place the point of fall somewhere near the Kentucky-Virginia line . . . near Harlan, Kentucky, and Norton, Virginia. Unfortunately, partly cloudy weather prevailed . . . which accounts for the scarcity of reports. . ."

From S2 and S3 we have plotted paths, from S4 the statement: "Direction was about W by N.W." However, S3 is considerably nearer the whole path than S2, yet S2 plots the beginning point just above Polaris while S3 gives it only half the altitude of Polaris. As S3 diagram is rather rough and by a person unused to astronomy while S2 is by someone who was personally interviewed by Bunch, and was able to so describe the path that it could be plotted on our map No. 1, I can only infer that the point S3 saw was not the *true* beginning point but one lower down. For both these stations the fireball disappeared behind natural obstructions, and hence the interesting azimuths for end point may not refer to exactly the same point on path. However, if they did, this point X is over $\lambda = 83° 32'$ W, $\phi = 37° 30'$ N at H = 42 km. There is reason to think that the object reached a very low altitude before exploding N.W. of Norton, Virginia, (S5) whose coordinates are $\lambda = 82° 39'$ W, $\phi = 36° 56'$ N. Its radiant must have been in about a = 130°. The slope of path was great, about 70° to 75° according to the diagrams at both S2 and S3. Such a slope would give a beginning height of some 150 km, which is higher than usual. This path angle, though, would by no means permit the explosion point being anywhere near S5, which is 107 km east of X. Yet the sound phenomena were so great at S5 and nearby places that it seems difficult to believe the end of the path was not fairly near. As the data on this point are so contradictory, we perforce leave the slope of the path (*i.e.*, the altitude of the radiant) unsolved. The final explosion probably took place near $\lambda = 83°$ W, $\phi = 37° 08'$ N. This is in mountainous country and any meteorites which may have fallen would be found now only by great good luck. S3 and S4 definitely state there was no trail left nor have I the original report of the person at S2 who gave one of "3 minutes duration." The one estimate for flight duration was 8 seconds. The bolide's color was blue-white. It is too bad that conditions combined to make the gathering of data difficult. Allen Tonkin and Wallace Jones, then A.M.S. member in the region, aided Bunch in securing reports. I am under obligations also to Miss Reilly of our staff for doing all the preliminary work on this and the two following objects, while I only interpreted the results and wrote them up.

On 1934 December 3/4 at $13^h 50^m$ ($1^h 50^m$ A.M., C.S.T., on December 4) a great bolide was reported from several stations in Arkansas. Using the two observations which gave the approximate directions of the explosion point, one of which also gave an estimated altitude, it is found that the explosion was over $\lambda = 90° 29'$ W, $\phi = 33° 57'$ N, which is a little west of Summerville, Mississippi. The bolide was moving to S.E. (?) and the explosion took place at H = 20 km. It certainly lasted several seconds and loud sounds were heard. It left a train and its head "was surrounded by a purplish haze." It lit up the country "like daylight." But for the hour of its appearance it would have attracted general attention. Meteorites should have been furnished by this body.

On his same night another wonderful fireball was reported by Second Officer R. W. Kloeppel, *Am. S. S. Christy Payne,* in $\lambda = 76° 57'$ W, $\phi = 32° 55'$ N, at 0816 G.M.T., which would correspond to $2^h 16^m$ A.M., C.S.T., or only 26 minutes after the Arkansas-Mississippi bolide. The following (abstracted) vivid account is taken from the *Hydrographic Bulletin,* U.S.N.: ". . . brilliant fireball . . . appeared 3° below Sirius and traveled to . . . 5° above Polaris. During its passage the fireball gradually grew until it appeared the size of a full Moon. The flaming trail was a beautiful bright red which slowly faded and turned to a dark

red, then dark green, and finally yellow. After 10 seconds of the passage the body turned into a veritable flame, and burst into fragments. About 2 seconds before this . . . was a separation and two fireballs appeared, one of which was slightly lower and smaller than the other. Both suddenly faded leaving a shower of sparks falling in all directions. During all this time the heavens were lighted as by day, and slightly towards the northward there seemed to appear continuous flashes as during a thunder storm. This ceased after the fireball disappeared. This phenomenon lasted 20 seconds. Two (near) vessels were clearly visible . . . the sky was overcast. . ." As the direction of motion of this bolide seems opposite to that of the one 26 minutes earlier there is no family connection *unless*, which is possible due to great ambiguity in the language of the one Arkansas observation used for direction, the motion was *from* not *to* the S.E. It may be added that on 1934 December 4 two stones fell at Farmville, North Carolina, which weighed 56 kg. Beyond these facts, unfortunately I do not have any information about this fall, even the hour of its occurrence. However, it is most interesting that on 1934 December 3/4 no less than three such outstanding meteors appeared over the southeastern part of the United States.

On 1935 October 24/25 at 17:11 E.S.T., a fireball brighter than Venus was observed by Bren Hallock at Gywnedd Valley, Pennsylvania, (S1), who reported it at once, sending in a good sketch of its path. A request in the papers netted 7 other reports, all from near Philadelphia. While these confirmed in general that the path was vertical none was far enough away or to the side to give usable parallactic angles, so heights could not be derived. For the plotted path at S1, $\lambda = 75° 17'$ W, $\phi = 40° 11'$ N, we find $\alpha_1 = 102°$, $\delta_1 = -8°$; $\alpha_2 = 102°$, $\delta_2 = -26°$, at $\theta = 109°$. This confirms that the path was practically vertical at S1 and also gives one coordinate of the radiant which must lie on the 102° right ascension circle. The duration was 2.1 seconds (mean of 4 estimates) and the color was white with perhaps tinges of blue-green. No long-enduring train was left.

In every one of the above reports just one more *good* observation would have allowed solutions for heights, path, lengths, etc. The writer therefore again takes occasion to beg of all persons interested in science to report bright fireballs without delay and in as full detail as possible. The one report someone was too indifferent to send in would be so often the key to the whole solution!

Flower Observatory of the University of Pennsylvania, Upper Darby, Pennsylvania, 1943 September 11.

Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD
Department of Astronomy, University of California, Los Angeles

President of the Society: LINCOLN LA PAZ, Department of Mathematics, Ohio State University, Columbus

Secretary of the Society: C. H. CLEMINSHAW, Griffith Observatory, Los Angeles, and Department of Astronomy, University of Southern California, Los Angeles

The Tenth-Anniversary Message from the President of the Society

By LINCOLN LA PAZ
Department of Mathematics, Ohio State University, Columbus

The present summer (August 21-22, 1943) marks the tenth anniversary of

the First (Organization) Meeting of the Society for Research on Meteorites, and it therefore seems appropriate to review briefly developments in the field of meteoritics that have occurred within the first decade of the Society's existence and to summarize the accomplishments of the Society in this same period. We shall be able thus to secure some estimate of the extent to which the organization has fulfilled the goals envisaged by its founders, namely, "to promote the discovery, collection, investigation, and preservation of meteorites and to advance the science of meteoritics and related sciences through the increase and diffusion of knowledge concerning meteorites and meteors" (*Constitution*, Art. 1, Sect. 2).

Among the outstanding problems in the field of meteoritics are those of the place, mode, and time of origin of the cosmic masses that give rise to the luminous phenomena of meteors and, in exceptional cases, survive transit through the atmosphere and strike the surface of the Earth. In the decade just past, notable contributions have been made to the solution of each of these problems. Compelling evidence of the importance of what has been called the interstellar meteoritic component has been published; the older disintegration theories no longer monopolize the field of speculation as to the origin of meteorites and comets but now share it with the theory of electrostatic accumulation, and naive conjectures as to the age of meteorites have been replaced by carefully controlled experimental age-determinations based on well-founded physical principles. From the field of physics has come also the startling suggestion that whatever may be the place, mode, and time of origin of the meteorites, these bodies, as regards their fundamental material constitution, fall into two great classes, the terrene and the contraterrene meteorites. Finally, theoretical investigation and painstaking observational work have cast doubt on the supposition that the Moon is absolutely devoid of an atmosphere and have strengthened belief in the possibility of detecting lunar meteors.

If we fix attention on the terrestrial rather than the cosmic aspect of meteoritics, the last decade has been equally fruitful as regards new developments. At long last, the existence of meteorite craters has been universally admitted, and intensive exploration of these important topographic features of the Earth's surface, not alone by the methods of geophysical prospecting but also by methodical excavation, has been carried out at numerous localities; it has been finally recognized that meteorites are distributed in three dimensions in the Earth and are scattered not merely on its surface, with the result that more or less haphazard, non-instrumental searches are now supplemented or superseded by systematic surveys with properly designed meteorite detectors; finally, it should be pointed out that recent advances in physical metallurgy, particularly those relating to the crystallographic mechanisms established for the transformation from the high-temperature, face-centered, cubic lattice of γ-iron to the low-temperature, body-centered, cubic lattice of α-iron have been employed in the interpretation of the metal structures found in meteorites and promise to throw most important light on the origin and history of these bodies.

Examination of the more than six hundred pages contained in the several volumes of the CONTRIBUTIONS OF THE SOCIETY and in the earlier NOTES, published under the able editorship of our first President, will disclose that, either by original researches or by expository papers, members of the Society for Research on Meteorites have materially advanced "the science of meteoritics and related sciences through the increase and diffusion of knowledge" in each of the important

sub-fields referred to in earlier paragraphs and in many others not specifically mentioned there. As regards "the discovery, collection, investigation, and preservation of meteorites," one needs to direct attention only to the First, Second, and Third Catalogs of Meteoritic Discoveries Reported to the Society for Research on Meteorites (see *C.S.R.M.*, **1**, No. 3, 41, 1937; **2**, 96, 1939; **2**, 227, 1940; or *P. A.*, **45**, 449; **47**, 209; **48**, 555), in order clearly to establish that members of the Society, and in particular its second President, are responsible for more than half of all the meteorites now being recovered in the world. The evidence just submitted surely justifies one in concluding that to date the Society for Research on Meteorites has satisfactorily fulfilled the purposes for which it was organized. Independent evidence, pointing in the same direction, is to be found not only in the greatly increased membership of the Society (see *C.S.R.M.*, **2**, 296; *P. A.*, **49**, 444, 1941), which proves that it has successfully met a real need among scientists, professional as well as amateur, but also in the cordial acceptance granted to the Society by older scientific organizations, such as the American Association for the Advancement of Science (see *C.S.R.M.*, **1**, No. 1, 23, 1935; **2**, 94, 1939; or *P. A.*, **43**, 383; **47**, 157).

As the writer pointed out at the Eighth Meeting, in June, 1941, the war years will constitute a critical epoch in the history of our Society. At the sacrifice of their personal scientific interests and ambitions, the officers and members of the Society for Research on Meteorites are now gladly contributing to the war effort. Inevitably, heavier and heavier demands will be made upon their time, their energy, and their financial resources. To date, the momentum of the Society's phenomenal development in the first eight years of its existence has carried it over even such a handicap as the omission of annual meetings, in the course of the last two years. We can hope only that the interest and enthusiasm of its membership will suffice to maintain the Society through the mounting hardships of the darker years ahead.

A Study of the Multiple Meteoritic Falls of the World

By GEORGE H. HERBIG
Department of Astronomy, University of California, Los Angeles

ABSTRACT

The meteoritic falls of the world have been studied in an attempt to learn whether they support the hypothesis that a governing cause of multiple falls is the fact that stones are more friable than irons and are thus more likely to disintegrate under the effects of external forces. A statistical test has been applied to the data and has been found strongly to support this hypothesis.

A shower of meteorites is due presumably to the breaking-up of an original body, either in the Earth's atmosphere or in space. If such is the case, it is natural to assume that the breaking-up process would be more effective for the friable aerolites than for the tough siderites. It is of interest to see whether the operation of this effect can be detected in the statistics of the known meteoritic falls of the world. An excellent source of such material is the card catalog of these falls maintained by Dr. Frederick C. Leonard, and it was from this manuscript catalog that the data were obtained. The following table lists the observed frequencies of single and multiple falls for the 3 main types of meteorites, namely, aerolites, siderites, and siderolites. For many multiple falls, the exact number of individuals found has not been published, having been described merely as

"several," "many," "numerous," "shower," "fragments," *etc.* These falls of indefinite multiplicity have all been collected under the headings "several," "many," *etc.*, at the foot of the table.

TABLE 1

THE OBSERVED FREQUENCIES OF MULTIPLE FALLS

Multiplicity (Number of Individuals Found)	Aerolites (Stones)	Siderites (Irons)	Siderolites (Stony Irons)
1	520	431	47
2	88	23	1
3	36	10	3
4	21	9	1
5	9	2	2
6	12	5	
7	3		
8	5		
9	3		
10	3		
11	4		
12	3		
14	2	1	
19	1		
20	4		
22	1		
24	1		
26	1		
28	1		
30	3		
33	1		
40	3		
50	2		
51		1	
71	1		
80	1		
100	4		
104	1		
200-300	1		
500	1		
2000-3000	3		
15,000	1		
100,000	1		
"Several"	38	6	4
"Many"	35	3	1
"Hundreds"			1
"Thousands"			1

In the accompanying tabulation, the large crater-forming falls of Canyon Diablo (Arizona), Henbury (Australia), Wabar (Arabia), Odessa (Texas), and the Island of Ösel (Estonia) have not been included, nor have certain falls having suspected double indentifications, nor falls of uncertain multiplicity or of doubtful meteoritic nature. For these reasons, 28 falls have been omitted.

An inspection of the tabulated frequencies suggests that aerolites definitely show a stronger tendency to occur as multiple falls than do siderites, but the difference in the total number of each type, as well as the irregular nature of the plotted frequency-distributions, makes it difficult to reach a final conclusion. It is desirable, then, to apply to these data some form of test, which will furnish a quantitative index of the degree of dissimilarity between the breaking-up tendencies of the different types of meteorites. As the method of contingency furnishes

such a criterion, a brief description of it will be in order.

Let $a_1, a_2, a_3, \ldots, a_k$ and $b_1, b_2, b_3, \ldots, b_k$ represent the observed frequencies of fall of 2 types of meteorites, say aerolites and siderites, classified according to the number of individuals recovered (the multiplicities), $m_1, m_2, m_3, \ldots, m_k$. These may be arranged in a "contingency table," as follows:

	m_1	m_2	m_3	...	m_i	...	m_k	
Aerolites	a_1	a_2	a_3	...	a_i	...	a_k	$\sum_1^k a_i$
Siderites	b_1	b_2	b_3	...	b_i	...	b_k	$\sum_1^k b_i$
	a_1+b_1	a_2+b_2	a_3+b_3	...	a_i+b_i	...	a_k+b_k	N

Each column and each row have been summed separately; it is obvious that the sum of all the columns and the sum of all the rows are equal to each other and to the grand total of all the frequencies in the table, N. We shall assume that the laws governing the breaking-up of meteorites have no respect for their compositions; *i.e.*, that the frequency-distribution of the multiple falls of stones and of irons is the same. If such is the case, the expected value of any a or b may be calculated from the consideration that it will be in the same ratio to the total number of falls (both aerolitic and sideritic), of that particular multiplicity, as the sum of the frequencies of all aerolitic falls (or sideritic falls, depending upon whether we are calculating an a or a b) is to the total frequency, N. Hence, denoting the expected values by primes, we obtain:

$$a_i' = (a_i + b_i)\frac{\sum_1^k a_i}{N}$$

$$b_i' = (a_i + b_i)\frac{\sum_1^k b_i}{N}$$

In general, on account of sampling errors arising from such things as our ignorance of the true total number of the members of a multiple fall, from the fact that the simple terms "aerolites" and "siderites" do not denote perfectly homogeneous classes, and also because there may be some physical effect operating to produce dissimilar distributions, these expected frequencies will not be equal to those observed. The χ^2-test affords a method of testing the truth or falsity of our hypothesis of identical distributions, on the basis of the differences between observed and expected values. The quantity χ^2 is defined as the square of the difference between observed and expected frequencies in any cell, divided by the expected value, summed for all cells in the contingency table. For the example being considered,

$$\chi^2 = \sum_1^k \frac{(a_i - a_i')^2}{a_i'} + \sum_1^k \frac{(b_i - b_i')^2}{b_i'}$$

In addition, it is necessary to employ n, the number of "degrees of freedom," in the table: the number of cells which we may fill arbitrarily without affecting the row- or column-totals. Then, if χ^2 is large, it is because the observed frequencies

differ widely from those expected. To decide whether this condition exists because of a significant departure from our hypothesis of identical distributions, or is due merely to statistical fluctuations, it is necessary to calculate P, the probability that purely random sampling would give differences as large as, or larger than, those actually found. If P is very small, then it must be concluded that the hypothesis of indentical frequency-distributions for stones and for irons is false; *i.e.*, that there is, then, a significant difference between the disintegrative properties of these 2 types of meteorites.

In applying this method to the data, one precaution must be observed. We are, in effect, comparing our discontinuous data, grouped at certain discrete values of the independent variable, with the theoretical χ^2-distribution, a continuous function. This approximation is satisfactory, provided the expected values in the cells are always at least about 5. Where the falls are sparse, in the high multiplicities, it has been necessary often to group a wide range of multiplicities under one heading, in order to satisfy this requirement at least approximately. The following table lists the data for aerolites and siderites; boldface type indicates observed frequencies and italics the expected values:

TABLE 2

THE OBSERVED FREQUENCY-DISTRIBUTIONS

Multiplicity	1	2	3	4	5	6	7-9	10-14	15-30	31-100,000	
Aerolites	**520**	**88**	**36**	**21**	**9**	**12**	**11**	**12**	**12**	**20**	741
	576	*67*	*28*	*18*	*7*	*10*	*7*	*8*	*7*	*13*	
Siderites	**431**	**23**	**10**	**9**	**2**	**5**	**0**	**1**	**0**	**1**	482
	375	*44*	*18*	*12*	*4*	*7*	*4*	*5*	*5*	*8*	
Totals	951	111	46	30	11	17	11	13	12	21	1223

χ^2 is found to be 70.0, and the number of degrees of freedom is 9. Ordinarily, P may be taken from Pearson's tables,[1] but when it is very small it must be calculated.[2] In this particular case, $P = 0.000000000015$. This fact indicates that the long wing on the frequency-distribution diagram for the aerolites is a highly significant feature, as it, or a longer one, would occur by chance in only 15 trials, or less, out of a million million! It is unfortunate that so little information is available for many falls of undoubtedly high multiplicity,[3] as the greater shattering tendencies of the aerolites are conspicuous in such cases.

The siderolites cannot be advantageously treated in the preceding manner because of the relatively few known falls of this kind. Accordingly, the multiplicity-classification has been reduced to "single" and "multiple" falls, in order to compare them with the siderites, in a 2×2 table:

TABLE 3

2×2 TABLE OF SIDERITIC AND SIDEROLITIC FALLS

	Single	Multiple	
Siderites	**431**	**51**	482
	428	*54*	
Siderolites	**47**	**9**	56
	50	*6*	
Totals	478	60	538

χ^2 is found to be 1.868, corresponding to a P of 0.17. This fact means that siderolites show indications of breaking up more easily than do siderites (as would be expected from their mixed composition), but the tendency is not sufficiently marked to be ascribed definitely to the operation of some systematic process.

Another approach to the question of whether multiple falls are the result of a breaking-up process would be afforded by the comparison of the mass-frequency-distribution of a well-studied shower with that determined from laboratory experiments with exploded bodies. The work of Suzuki and Nagasima[4] indicates that such a distribution follows the relationship

$$y = (A - B \log x)^2,$$

where y represents the number and x the mass of the fragments, and A and B are constants such that $A \geqslant B \log x$. The data of Foote[5] on the Holbrook (Arizona) shower have been plotted, and while insufficient information is given for a detailed comparison between the laboratory and shower distributions, the two are not in conflict.

Whether the breaking-up process indicated by this study takes place before or after the original meteoritic mass strikes the Earth's atmosphere is uncertain, and it would be pointless to repeat the arguments for both points of view,[6] but it is difficult to see how an explosion violent enough to disrupt a meteorite while in space could help scattering the fragments to such an extent that it would be impossible for them to encounter the Earth as a swarm. Certainly their mutual gravitational attractions would be too feeble to resist any such dispersing force.

It is a pleasure to thank Dr. Paul G. Hoel, of the Department of Mathematics of the University of California at Los Angeles, for his valuable advice on the statistical aspects of this study and also Mr. Herbert P. Arklin, a member of Dr. Leonard's class in meteoritics in the spring term of 1943, for suggesting the problem.

References and Notes

[1] Karl Pearson, *Tables for Statisticians and Biometricians*, Pt. I, Table XII, Cambridge University Press, 1924. Pearson's argument n' is the number of degrees of freedom increased by 1.

[2] *Op. cit.*, *n.* (1), *ante*, eqs. (xxix), p. xxxi.

[3] Of the 73 aerolitic falls omitted from Table 2 for reasons of unknown multiplicity, 26 were described as a "shower," 2 as "numerous," and 7 as "many." Of the sideritic falls omitted, 2 were described as "many" and 1 as "numerous."

[4] *Scientific Papers of the Institute of Physical and Chemical Research*, **34**, 1086-1122, 1938.

[5] *Am. Jour. Sci.*, **34**, 437-56, 1912.

[6] Summarized by Nininger, *C.S.R.M.*, **1**, No. 1, 5-9; *P. A.*, **43**, 121-6, 1935.

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

Charts of North Polar Sequence: The A.A.V.S.O. has ready for distribution three charts, on different scales, of the North Polar Sequence with magnitudes indicated on the visual system. The scales used are, respectively, $1^\circ = 25.4$ mm., from the Bonner DM.; $20'' = 1$ mm., from a Harvard chart; and $4\overset{m}{.}6 = 1$ mm.,

from a Mount Wilson chart. These charts are the handiwork of Mr. D. F. Brocchi, chairman of the Chart Committee, and blueprint copies may be obtained at cost price by addressing the chart curator, Mr. F. Hartmann, 191-34 114th Drive, St. Albans (12), N. Y.

Variable Star Observations in Europe: Copies of *Beobachtungs-Zirkular* received in this country in recent months indicate that during 1942 variable star observing was being carried on in Europe with, seemingly, little interruption. Although two observers, Messrs. Ahnert and Loreta, have been unable to communicate their results to the A.A.V.S.O. headquarters, they are evidently pursuing their variable star work with diligence.

In the *Zirkular* for 1942 appear many observed dates of maxima and minima, especially of the long-period variables. It is also to be noted that the specially active variables, such as R Coronae Borealis, Gamma Cassiopeiae, SS Cygni, Nova Cygni, 1942, and Nova Puppis, 1942, have received due attention. Although notices of the independent discovery of Nova Puppis by Finsler and Nakahara are given, the actual dates and times of discovery are omitted.

Nova Puppis, 1942: Observations of Nova Puppis received from observers in the southern hemisphere indicate that the nova steadily decreased in light to nearly the 8th magnitude at the end of June of this year. The stand-still in brightness at slightly below the 6th magnitude, as noted by some of the northern observers during the months of February through April, has not been confirmed by those who could observe the star under more favorable conditions of altitude.

To date, nearly 500 estimates as made by members of the A.A.V.S.O. have been communicated here, besides a nearly equal number which have appeared in print as made by other observers.

By early November, when the nova will again be favorably placed for observation in both hemispheres, observations should be resumed, when it is expected that the star will be somewhat fainter, probably about magnitude 8.5.

Current Comments on Variable Stars: Gamma Cassiopeiae, which hovered around magnitude 2.9 early in the year, appears to have brightened to magnitude 2.7 during the early summer months and has now decreased again to magnitude 2.9.

RX Andromedae, which during 1942 passed through one of its stages of smaller amplitude variations, has again resumed its normal periodic activity, especially since June, 1943, when cycles of 20 to 25 days have been observed.

Z Camelopardalis, a variable of the same type as RX Andromedae, has for the past year held closely to its normal type of variation; a range of from two to two and a half magnitudes, in cycles averaging 25 days.

Mira, o Ceti, attained a maximum magnitude of 3.0 at the end of March, 1943, just before the star reached conjunction with the Sun. It is now of the 8th magnitude, with the next maximum due to occur early in March, 1944.

The brightest maximum ever recorded of o Ceti has just come to light in a perusal by Nordemark of the old records of the Swedish astronomer, Wargentina, who observed the star from 1751 to 1782. He noted a maximum magnitude of 1.5 in November, 1779. The brightest magnitude attained since that date appears to be that of December, 1906, when the star was as bright as 2.1. The average magnitude at maximum is about 3.5, with a wide divergence in bright-

ness between individual maxima. A few maxima have reached only to the 5th magnitude, as was the case in 1924.

SU Tauri is well on its way to normal maximum brightness, unless the unexpected happens. On September 1 it had become brighter than the 11th magnitude. The star has been below normal maximum brightness since April 15, 1942, with a secondary rise toward maximum last December, when it rose to magnitude 11.1 only.

SS Aurigae. No maximum of this star has been observed since the one of last February. To be sure, for nearly two months, the variable was too near the Sun for favorable observation. Now that the region is becoming better placed for observation each night, the star should be followed more closely in order that the next maximum may be well observed.

Nova Pictoris, 1925, is slowly declining in light, having attained magnitude 10.4 late in June of this year. This indicates a decrease in light amounting to two tenths of a magnitude in the past year.

U Geminorum, after nearly five months of inactivity, passed through a narrow-type maximum early in September. Mr. J. W. Meek of Glendale, California, was apparently the only one who observed the maximum.

T Pyxidis, the recurring-type of nova which has had three well-observed maxima in the past—1890, 1902, and 1920—is still at, or near, magnitude 14.0. It should be observed at short intervals, if we are to expect another maximum after a lapse of twenty to twenty-five years.

V Hydrae was at one of its deep, long-term minima early this year and has now brightened to magnitude 10.0.

S Apodis remains at, or near, minimum, at magnitude 13.0. It began its descent to minimum early in January, 1943.

R Coronae Borealis has definitely reached normal maximum brightness, after the decrease in light which began a year ago. Like SU Tauri, it rose to a secondary maximum, magnitude 7.8, in December, 1942.

Nova (RS) Ophiuchi continues to oscillate between magnitudes 10.5 and 12.0 in an irregular manner.

Nova (DQ) Herculis has dropped to magnitude 12.0, a decrease of nearly half a magnitude in the past year.

RY Sagittarii, like SU Tauri, is gradually increasing in brightness to normal maximum. There have been evidences of two secondary maxima since the star began to fade away a year ago.

χ *Cygni* is at minimum, magnitude 13.5, and its rise to maximum should be carefully observed in order to note whether or not a still-stand, or slowing-up, in brightness occurs on the way to maximum, which is due in February, 1944.

V Delphini is well on its way to maximum. The increase in light from minimum has been exceedingly rapid; some four magnitudes in less than a month.

Nova Cygni, 1942, continues to remain near its secondary maximum—similar in behavior to that of DQ Herculis, 1934—only very slowly decreasing in brightness. It is now about magnitude 13.0.

SS Cygni was at maximum in August, preceded by an interval of about 90 days when the star remained at nearly constant light. This maximum marks the 333rd which has occurred since the discovery of the star as a variable in 1896.

RU Pegasi was at a well-observed maximum in August. A. H. Joy pointed out earlier that at maximum the spectrum of the star is continuous, with fairly strong emission lines of hydrogen and helium. These same lines are somewhat stronger at minimum where they are set against a background absorption spectrum of a dwarf G3 type. This spectrum differs from that of SS Cygni at minimum. Joy also states that if RU Pegasi is typical of the SS Cygni group, then these observations confirm the conclusion that these stars fall on the main sequence.

G. E. Ensor: Word, somewhat delayed, and received from observers in South Africa, tells of the death on June 9, at Pretoria, of the amateur astronomer, G. E. Ensor. He had contributed several thousand observations of variable stars to the A.A.V.S.O. during his fifteen years of activity in that field, ceasing to communicate his results only in 1940, when poor health prevented him from undertaking further observations. Mr. Ensor was the original discoverer of a comet in 1925, and co-discoverer, with H. E. Houghton, of another in 1932.

George R. Griffin: The first war casualty, as far as we know, among the A.A.V.S.O. occurred recently when our very promising observer of Portland, Maine, George R. Griffin, met accidental death at Santa Maria, California. Corporal Griffin was serving as meteorologist in the Army Air Forces, having enlisted about a year ago. Although only 22 years of age, he had become a very ardent and proficient observer with a reflecting telescope of his own making.

Observers and Observations: A very commendable list of observations has just been received from our observer in India, Mr. R. G. Chandra, the first since January of this year. We have also received a lengthy contribution from a new observer, Mr. H. E. Krumm, of Cape Town, South Africa. Mr. James C. Robinson of Clovis, New Mexico, also sends in an initial report.

The total of 3676 observations contributed during August is the largest which has been reported since September, 1941.

Observer	July—1943—August Var.	Ests.	Var.	Ests.
Bappu	28	113	..	..
Blunck	29	35	29	35
Boone	12	12	27	27
Bouton	19	19	28	35
Buckstaff	24	60	26	97
Chandra	..	..	78	115
Cousins	44	96	51	149
Dafter	..	..	10	54
Dawson	..	..	1	16
Duffie	20	21	30	50
Fernald	219	409	233	535
Ford	..	..	49	49
Friton	13	21	..	..
Garneau	32	49	37	51
Halbach	..	..	35	35
Hale	..	..	3	5
Harris	25	25	20	20
Hartmann	91	123	127	133
Heckencamp	..	..	11	20
Herbig	85	102	..	..
Hiett	..	..	18	42
Holt	64	89	41	50
Howarth	15	15	16	26
Jones	38	67	50	140
Kearons	87	127	85	154
Kelly	10	14	12	14
de Koch	66	296	72	305
Koons	41	51	34	37
Krumm	..	..	24	185
Labrecque	23	31	27	47
Luft	..	..	5	63
Manlin	67	68	61	72
Meek	30	142	32	236
Nadeau	92	125	98	195
Parks	28	45	25	47
Peltier	80	142	165	254
Reeves	2	8	3	8
Robinson	..	..	21	27
Rosebrugh	9	41	7	46
Sandage	14	19	10	12
Schoenke	29	65	37	48
Segars	9	15	14	47
Sill	43	43	38	38
Topham	15	15	19	19
Vohman	17	27	20	36
Webb	11	11	16	21
Weber	85	85	81	81
Totals		2626		3676

September 14, 1943.

Comet Notes

By G. VAN BIESBROECK

There has been a lull in cometary activity this summer. COMET 1942 *g* (WHIPPLE) was followed here until August 2 when it was last recorded at low altitude as a vague nebulosity of magnitude 16.

COMET 1943 *a* (OTERMA) had to be given up already earlier. The last observation here was on July 2 and it is doubtful if further records have been made elsewhere on account of the approaching conjunction with the Sun. The diameter of the coma was measured as 15″ on this late date and the magnitude estimated as 16. Two preliminary elliptic orbits have been deduced for this object. (*Harvard Announcement Cards*, 660-662):

Computer	Cunningham and Thomas	Herbig and McMullin
Perihelion time U.T.	1942 Oct. 18.1040	1942 Sept. 13.65334
Perihelion to node	5°000	359°00632
Node	154.850	154.93204
Inclination	3.967	3.98111
Period (years)	8.00	7.953060
Perihelion distance	3.44 A.U.	3.41564 A.U.
Eccentricity	0.139135	0.1427105

This establishes beyond doubt that we have to do here with a short-period comet, whose orbit lies very near to the ecliptic and whose eccentricity is so small that it seems safe to predict it will be possible to follow it throughout its orbit. PERIODIC COMET SCHWASSMANN-WACHMANN (1925 II) was the first one found of this kind. It has been under observation year after year since 1927 passing through aphelion. Frequently it has been mentioned on account of its unexplained enormous changes in brightness and appearance. The new object will be interesting to follow from this point of view.

There has been in the literature a misleading statement about this comet. *Science News* of September 3 stated that COMET OTERMA may be actually an asteroid! This statement results from the comment added by the second computers in publishing their results: "It will be noted that the eccentricity appears to group this object with the asteroids rather than the comets," and they call attention to the resemblance between the comet's orbit and that of the asteroid 334 (Chicago). It is well known that there is no clear-cut distinction between orbits of periodic comets and those of asteroids. Eccentricities among the latter run up as high as 0.65 (Hidalgo) and some have high inclinations which are characteristic of the former. What distinguishes the two types of objects is their physical nature and not their orbits. Asteroids are small solidified bodies which appear stellar except the very largest which show a measurable sharply defined disc. Comets occupy a much larger volume; their material is in a tenuous state which gives even the faintest ones a fuzzy appearance and shows that they are a different class of objects. They are undergoing considerable and rapid changes through a mechanism originating in the Sun's radiation, while asteroids are stable, dead bodies from a physical point of view. Speculations about comets, in the course of centuries, losing the material forming the nebulosity and being gradually reduced to a stellar nucleus are perfectly justified. But one can hardly conceive a condensed solid body starting to emit material for a luminous envelope many times its size and passing from the state of an asteroid to that of a comet.

It should not be forgotten also that, owing to near approaches to major planets, comets may have their orbits altered considerably. Cunningham notes that his orbit indicates that such has been the case with the present object, which at its aphelion in 1938 remained for a considerable time within half an astronomical unit from Jupiter, adding, "it appears probable that the present orbit is very much different from the one which it had previous to that encounter." The present orbit, situated half-way between the path of Mars and that of Jupiter, is such that the comet should become observable again this coming winter.

The search for the expected COMET D'ARREST has not led to its recovery so far. It should be an evening object theoretically near maximum brightness at this time but it may be faint yet and brighten up after perihelion passage (September 23) as it did when last seen in 1923.

Two more periodic comets await recovery in the morning sky this fall. The following ephemerides are given in the *B. A. A. Handbook* for 1943:

Object	COMET SCHAUMASSE		COMET DANIEL	
Perihelion date	1943 Nov. 4		1943 Nov. 22	
Computer	Sumner		Henderson and Wichello	
	α	δ	α	δ
	h m	° ′	h m	° ′
Sept. 25	9 08.5	+18 35	5 16.8	+ 8 26
Oct. 3	9 41.1	17 06	33.1	10 01
11	10 13.8	15 18	5 49.0	11 48
19	10 46.3	13 14	6 4.5	13 54
27	11 18.3	10 56	18.9	16 21
Nov. 4	11 49.4	8 31	32.2	19 15
12	12 19.6	+ 6 02	6 44.2	+22 39

Owing to difficulties of transmission of information even among allied nations some confusion has arisen in the cometary nomenclature of last year. Some discoveries become known in this country after the object has ceased to be observable. Our active Russian colleagues observed several comets independently, not knowing of their earlier discovery in other parts of the world. It is not probable that the following list will require revision.

COMETS IN 1942

Designation	Discover	Earliest Position
1942 *a*	WHIPPLE-BERNASCONI-KULIN	Jan. 25—Harvard
b	OTERMA	Feb. 12—Turku
c	VAISALA	March 12—Turku
d	PERIODIC GRIGG-SKJELLRUP	April 10—Williams Bay
e	PERIODIC FORBES	June 15—Williams Bay
f	OTERMA-TEVZADZE-NEUJMIN	Nov. 6—Turku
g	WHIPPLE-FEDTKE-TEVZADZE	Dec. 8—Harvard

COMET SCHWASSMANN-WACHMANN I, which is observed every year, receives no other designation.

Williams Bay, Wisconsin, September 10, 1943.

General Notes

Dr. E. C. Slipher of the Lowell Observatory, Flagstaff, Arizona, has recently received the honorary degree of Doctor of Science from the University of Arizona.—(*Sky and Telescope,* September, 1943.)

Dr. Frederick C. Leonard, Chairman of the Department of Astronomy, University of California, Los Angeles, has been in residence at the Lick Observatory of the University, on Mt. Hamilton, since July 6, 1943, engaged in a program of research on double stars.

Astronomers everywhere will rejoice over the many honors that have recently come to the Astronomer Royal, Dr. Henry Spencer Jones. He was awarded the Gold Medal of the Royal Astronomical Society for 1943 in recognition of his work on the solar parallax from Eros observations. This spring he was elected a Foreign Associate of the National Academy of Sciences. The most recent news is that his name appeared on the Birthday Honors list of the King of England, with Dr. Spencer Jones receiving a knighthood. . . The R.A.S. and the A.A.S. have both acquired new presidents. Dr. E. A. Milne was elected president of the R.A.S. to succeed Dr. S. Chapman; Dr. Harlow Shapley has succeeded Dr. Joel Stebbins as president of the A.A.S.—(*Monthly Astronomical Newsletter,* No. 12.)

The papers from Germany include some recent issues of the *Astronomische Nachrichten,* the *Berliner Jahrbuch* for 1943, *Kleine Planeten* in 1943, and copies of two books. The first is entitled "Sterne und Sternsysteme" by Wilhelm Becker, the second is "Theorien der Kosmologie" by Otto Heckmann. In spite of the war the Copernicus Institut has succeeded in publishing the 1940 edition of the "Astronomischer Jahresbericht."—(*Monthly Astronomical Newsletter,* No. 12.)

Texas Observers' Bulletin is the name given to a periodical which has now appeared in 141 issues over a period of more than ten years, the latest issue at hand being that for September, 1943. It is issued in mimeographed form and usually consists of four pages. The contents pertain to astronomical phenomena, especially such as are of significance to Texas and its environs. Even though Texas is very large, most astronomical events cannot be so restricted. Occasionally a meteoritic display may be so limited. The *Bulletin* therefore, perforce, has wider connections. The success and continuity of this publication are due to the initiative, energy, and perseverance of Mr. Oscar E. Monnig, Fort Worth, Texas, who is almost solely responsible for it. It furnishes interesting reading for those persons interested in astronomy as amateurs. The subscription price is one dollar a year.

An Unprofitable Visit

About a year ago, the writer was invited to visit a past president of the Scientific Astrologers Association. Since I was going to New York the following week, an appointment was made and in due course I went to the hotel suite for the interview.

The writer was wearing a Sigma Xi key and a Rotary button. The Scientific Astrologer asked if these were Masonic. I replied that they were not, without offering any explanation.

I was shown a copy of the current Astrologers Almanac and asked what planet was meant by Herschel. This brought the correct response as well as a chiding for not knowing the answer.

The next information sought was the place of my birth. I replied Latitude 40° N. and Longitude 75° W. These are correct within a few minutes of arc but it seemed necessary to give the name of the town. This name was long and unfamiliar and apparently did not help.

When was I born? I gave the year, day, and hour as nearly as I could remember. The Scientific Astrologer then looked for the Almanac for that year and could not find it. I had a sheet of paper in my hand to make notes of important things that might be in store for me and on the inside of the folded paper were all the data for the given date that might be relevant. Since I was not asked if I might know any of these details, I did not deem it necessary to offer the information. The interview had not disclosed anything of the immediate present. What the future might have been would probably have been entertaining if not scientific or true. J.H.P.

Copernican Quadricentennial Observed by The Joliet Astronomical Society

Janusz Stamirowski, director of the Polish information center for the midwest, made a stirring address before members of the Joliet Astronomical Society on the evening of May 12 in describing the contributions of the Polish people in the present war as of prime importance. Mr. Stamirowski, who was an armaments manufacturer and army officer, experienced both the fall of Poland and the fall of France.

Speaking on the subject of "Poland, the Homeland of Copernicus" which climaxed the society's observance of the 400th anniversary of Copernicus' death, he said that, just as Poland gave Copernicus to the world, so Poland had given the world an example of complete self-sacrifice that the democracies of the world might survive and the great principles for which the United Nations are now fighting might endure.

Preceding Mr. Stamirowski's address, Miss Alice Dombrowska gave an illustrated talk on the life of Copernicus. She concluded with the story of the Broken Note trumpet call which was played by William Welsch of the high school band. Everett C. Shaw read Sir Alfred Noyes' great poem on the death of Copernicus from the volume, "Watchers of the Sky."

The scientific contributions of the great Polish scientist who put forth the theory of the sun-centered universe were discussed by Robert L. Price who quoted eminent authorities in their appraisal of his work.

Richard Comer, Jack Meyerhoff, and William Welsch, well-known trumpet trio of the high school band, played Paderewski's Minuet and the Polish national anthem. Later, accompanied by Miss Lillia Linden, they played Leonard's Triolet. Alex Zimmerman lead the group in the singing of the Star Spangled Banner and the Polish national anthem.

Raymond D. Cooke, president of the society, acted as master of ceremonies and mentioned the significance of the observance of this occasion throughout the civilized world. Frank M. Preucil took colored motion pictures of the speakers and guests as a record of the event. Souvenirs in the form of reproductions of a famous Copernicus picture which were obtained from Krakow, Poland, were presented to the guests.

The American and Polish flags held prominent positions.

Third Nation-wide Science Talent Search

The third annal Science Talent Search, a nation-wide quest for promising scientific ability among high school graduating seniors, will be conducted during the fall and winter months of the school year just opened, Watson Davis, Director of the Science Clubs of America, announced in Washington.

Open alike to boys and girls, the Science Talent Search will enlist the aid of high school principals and teachers who will administer tests and supply other necessary data. Westinghouse Science Scholarships totaling $11,000 will be awarded to at least 10, and possibly 40, of the young scientists of the future.

In addition, all 40 will attend a five-day Science Talent Institute on an all-expense trip to Washington next February.

In the second Talent Search, completed last spring, some 15,000 seniors requested examinations, 3,400 completed the requirements and 260 were awarded honorable mention. Of the 40 brought to Washington, 11 were girls and 29 boys.

Mr. Davis said that students in public, private, and parochial schools desiring to enter the Science Talent Search this fall will take a special aptitude examination under supervision of school officials in their home communities between December 3 and 27. The 40 who pass the examination, and qualify on the basis of personal and scholarship records and essays, will be named delegates to the Science Talent Institute.

Final examinations during sessions of the Institute will determine the award of two four-year Westinghouse Science Grand Scholarships of $2,400 each and eight four-year Westinghouse Science Scholarships of $400 each. One boy and one girl will be selected to receive the Grand Scholarships. The Westinghouse Electric & Manufacturing Company provides the scholarship awards as a contribution to the advancement of science in America.

Additional Westinghouse scholarships totaling $3,000 will be awarded at the discretion of the judges.

If any scholarship recipient should be drafted or enter other government war service, his scholarship will be held for his use later.

Book Review

Astronomical Society of the Pacific, *Leaflets*, Vol. III. (Astronomical Society of the Pacific, San Francisco, Calif. $3.00.)

This volume, containing Numbers 101-150, is a collection of fifty delightful essays on astronomy and related sciences. The articles are short (averaging eight pages in length) and are offered for the enjoyment of intelligent laymen rather than for skilled workers in astronomy. But, in every case, there is presented some entrancing aspect of the universe which is worthy of humble contemplation by the most learned scholar. According to reports, the *Leaflets* have been enthusiastically received by the members of our Armed Services. It would be hard to find more satisfying and refreshing reading than is contained in this little book. Astronomy stands out among the sciences because of its grandeur and beauty. Not the least of its wonders is its accessibility. The stars are to be found everywhere, and the appreciation of them is open to everyone. Volume III of the A.S.P. *Leaflets* will bring life-long pleasure to many new friends of the stars.

Carleton College. W. A. Calder.

POPULAR ASTRONOMY

CONTENTS

OCTOBER, 1943

FRANK SCHLESINGER, 1871-1943, WITH PLATE V, IDA BARNEY 409

THE PHYSICAL CHEMISTRY OF COMETS, P. SWINGS 412

THE ORIGIN OF THE LUNAR CRATERS (A SUMMARY), ROY K. MARSHALL 415

COPERNICUS AND SCIENCE; FROM YESTERDAY UNTIL TOMORROW, HARLAN TRUE STETSON 425

MARVELOUS VOYAGES — VIII, H. G. WELLS' THE TIME MACHINE, LAURENCE J. LAFLEUR 434

A ROSE COLORED IMAGE OF THE SUN, C. C. WYLIE 436

AURORA BOREALIS OF AUGUST 30-31, 1943, N. T. BOBROVNIKOFF 438

MARVELOUS VOYAGES—VIII, ERRORS IN H. G. WELLS' THE TIME MACHINE, LAURENCE J. LAFLEUR 438

The Planets in November, 1943 440

Occultation Reductions 441

Occultation Predictions 449

Meteors and Meteorites 450

Meteor notes from the American Meteor Society,—Contributions of the Society for Research on Meteorites: The tenth anniversary message from the president of the Society; A study of the multiple meteoritic falls of the world.

Variable Stars 459

Variable Star notes from the American Association of Variable Star Observers.

Comet Notes 463

Comet 1943 *a* (Oterma),—Periodic comet Schwassmann-Wachmann (1925 II),—Comet d'Arrest,—Comet Schaumasse,—Comet Daniel.

General Notes 465

Personal notices,—Texas Observers Bulletin,—An unprofitable visit,—Copernican Quadricentennial observed by the Joliet Astronomical Society,—Third nation-wide science talent search.

Book Review 467

Astronomical Society of the Pacific, *Leaflets.*

The principal articles of this magazine, beginning with Volume **15** (1907), are listed in the INTERNATIONAL INDEX TO PERIODICALS.

Y

409
412
415
425
434
436
438
38
40
41
49
50
59
3
5
7